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1911.

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THE ASSOCIATION was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 700 men. Its membership is divided into two principal classes, viz.: MEMBERS and ASSOCIATES. Members are divided into two classes, viz.: RESIDENT and NON-RESIDENT, — the former comprising those residing within the limits of New England, while the latter class includes those residing elsewhere. The INITIATION fee for the former class is FIVE dollars; for the latter, THREE dollars. The annual dues for both classes of Active membership are THREE dollars. Associate membership is open to firms or agents of firms engaged in dealing in water works supplies. The initiation fee for Associate membership is TEN dollars, and the annual dues FIFTEEN dollars. This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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THE PROPOSED ATLANTIC INTRA-COASTAL WATERWAYS.

BY EDWARD PARRISH, C.E., NEWPORT, R. I.

[*Read March 8, 1911.*]

At the Norfolk Convention of the Atlantic Deeper Waterway Association last fall, President Taft said that Speaker Cannon of the House of Representatives "could not see the use of building a canal within a biscuit's throw of the ocean." He then added that the reason was because he was from Illinois, and he thought that if he had him on the *Mayflower* off the mouth of Chesapeake Bay, with a good southeaster blowing up from Hatteras, and could then run him up to the mouth of the Potomac, he would appreciate the difference between the open ocean and a protected waterway.

Therein is clearly indicated an important reason for an intra-coastal canal, and I shall endeavor to enlarge somewhat upon it, and present for your consideration a few others.

It seems hardly necessary at this time to undertake any elaborate demonstration of the difference in cost, under conditions of fair competition, between rail and water transportation. I think the great economy of the latter form, where it can be secured, is generally conceded. A short time ago I was impressed by the sight of a train of cars, 50 in number, probably averaging 20 tons each (there were none of the large 40- or 50-ton cars in the train), carrying coal up the valley of the Pawtucket River, 1 000 tons being hauled by two locomotives. This load was one third of the

cargo of a single barge, which was one of three brought into Providence Harbor by a single tug.

The matter of water transportation has been highly developed in the ore-carrying trade on the Great Lakes, representing, with the coal-carrying trade on the Mississippi and Ohio, phenomenally low cost per ton-mile, amounting in the former to about .69 mills and in the latter to .376 mills.

These rates are largely due to the peculiar circumstances of the trade to which they apply, and can hardly be regarded as fair indices of what might be expected under usual commercial conditions existing along the Atlantic coast; but they both are evidences of the results that can be accomplished by an intelligent adaptation of all available means to a specific end. In the case of the ore-carrying on the Lakes, there was available a certain depth of water, and the vessels were built for it and in such a manner that the cargo could be both loaded and unloaded with a minimum delay; the terminals were designed with the same end in view and supplied with the most modern machines for handling the cargo — and in passing I might add that it is the exception rather than the rule to find any mechanical devices at our water terminals in other localities.

The low coal rates on the Mississippi and the Ohio rivers are largely due to the very cheap type of barges used, which are taken down with the current in charge of a tow-boat, the chief function of which is to guide the tow rather than to furnish the motive power for hauling the load.

It has not been my good fortune to have seen an analysis of these very low freight costs, but they doubtless contain the elements of interest on investment, insurance, maintenance, and administration expenses; but probably, as the lines are owned by the great steel corporation using the ore, they are free from that iniquitous basis of charge of "what the traffic will bear," and may reasonably represent a fair cost of the service.

Let me invite your attention for a moment to this matter of freight rates, which is one of such prime importance to the industrial life of New England, where practically every item of raw material and every pound of finished product pays tribute to the great transportation companies handling them for you. The

admirable report of the Fuel Committee of the Boston Chamber of Commerce states that New England paid approximately $100 000 000 for the single item of coal during the calendar year of 1908, the value of which at the mines was about $30 000 000, leaving a charge of $70 000 000 for its distribution. Is not this a sum the proper disbursement of which is worthy of the most careful consideration and demands an intelligent investigation of any means which can reasonably promise a reduction of the enormous outlay? Let us see for a moment how the principal of charging what the traffic will bear works in this case. The all-rail rate from the Pittsburg district to Worcester, Mass., on coal, about a year ago, and it has probably not materially changed since, was $3.10 (I take the liberty of giving you again the figures of the Fuel Committee report, which may be familiar to you but are of such import as to bear repetition many times). The tide-water rate is figured as follows:

Pittsburg to Philadelphia,	$1.65
Philadelphia to Providence,	.50
Transfer to cars and weighing,	.21
Providence to Worcester,	.85
Total,	$3.21

Eleven cents greater than the all-rail rate.

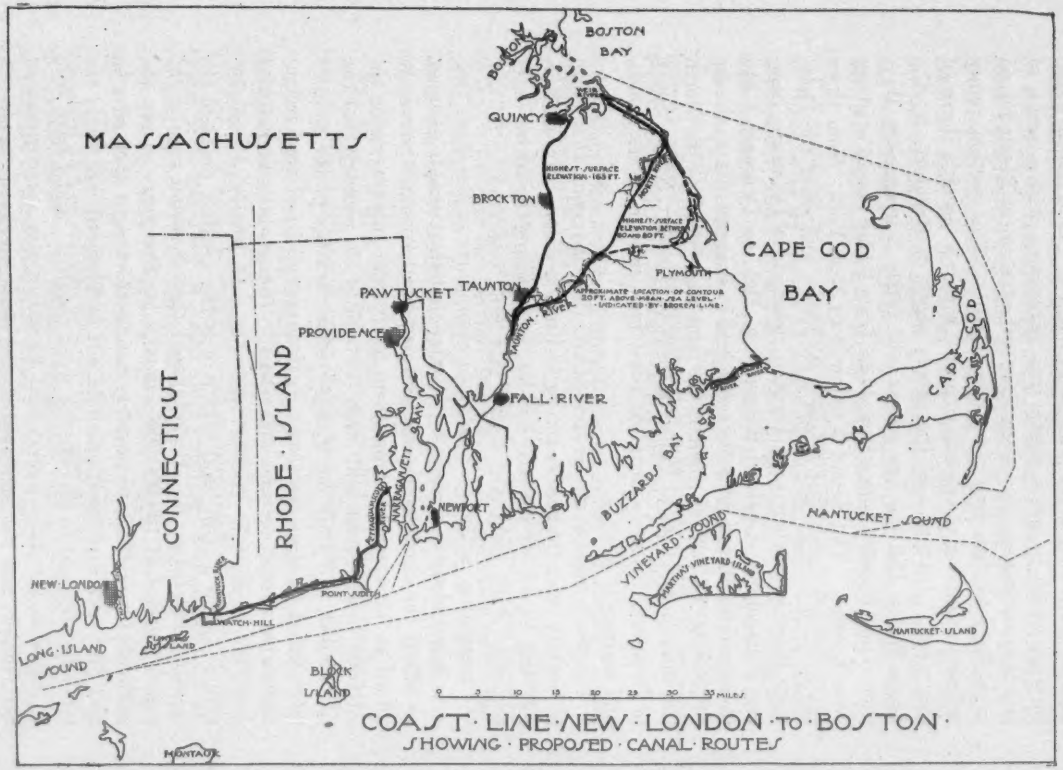
The distance from Pittsburg to Philadelphia is about 354 miles, giving a ton-mile rate of 4.7 mills; from Philadelphia to Providence by water is about 390 miles, giving a similar rate of 1.3 mills; and for the haul of 44 miles from Providence to Worcester a rate of 19.1 mills, or very close to 2 cents per mile, and this too after a charge of 21 cents for the transfer from the boat to the cars and weighing.

The all-rail distance from Pittsburg to Worcester is about 635 miles by way of Jersey City, which would give a ton-mile rate of 4.9 mills. This does not vary greatly from the rate from Pittsburg to Philadelphia, but you will observe is about one fourth the rate from Providence to Worcester, which would seem excessive even after making due allowance for the short haul of the latter. In fact, it appears that the rates are so arranged that the tide-water and all-rail rates meet about 50 miles from the coast. In

other words, any advantage to be derived from water transportation, which in the particular case we have been considering bears the ratio to all-rail transportation of 1.3 to 4.9, is to be confined to a narrow strip not exceeding 50 miles in width, bordering on the lines of waterways.

This disadvantage of distance from a water port is illustrated in another form which appears to me to involve great injustice although legally sanctioned by the Interstate Commerce Commission, and that is, permitting lower rail rates to points where tide water competition is encountered. Thus the rate to Taunton on lumber, I am informed, is $1.00 per ton more than it is to Fall River and New Bedford, although the lumber for the latter points is hauled through Taunton, which is either paying part of the Fall River and New Bedford bill as a penalty for not having established itself on the sea or is paying an entirely unnecessary tribute to the railroad company. Cotton, which is one of the great imports of New England and is rated as fourth-class freight, pays 10 cents per hundred from New York to Fall River or Providence, — within 2 cents of rates I have recently seen quoted from Baltimore to Liverpool. But the New England rate situation is well known to you all, and my reason for touching upon it here is that it may be fresh in your minds during this period of consideration of the projects that are being promoted by the Atlantic Deeper Waterway Association, which in general terms provide for a protected waterway along the Atlantic coast from Boston to Florida; that is, protected from the dangers of ocean navigation, thereby affording an available route for a cheaper type of carrier and in some cases saving very great distances between the points reached.

In outline the main project contemplates a canal connecting Boston Harbor with Narragansett Bay by way of the Taunton River and Mt. Hope Bay; thence across Narragansett Bay to Bissels Cove, a few miles below Wickford, R. I.; thence across a short divide into the valley of the Pettaquamscott River, south to a point back of Narragansett Pier. A curious feature of this stretch is found in the fact that although the valley is between two ranges of high, rocky hills, there is ample water in the river for navigation purposes in the upper two miles, reaching to a depth of 60 ft. Back of Narragansett Pier the line of the canal crosses


MASSACHUSETTS
BOSTON BAY
QUINCY
BROCKTON
HIGHEST SURFACE ELEVATION 163 FT.
HIGHEST SURFACE ELEVATION BETWEEN 80 AND 160 FT.
CAPE COD BAY
PLYMOUTH
PAWTUCKET
TAUNTON
APPROXIMATE LOCATION OF CONTOUR 20 FT. ABOVE MEAN SEA LEVEL INDICATED BY BROKEN LINE
PROVIDENCE
TAUNTON RIVER
CAPE COD
FALL RIVER
CONNECTICUT
RHODE ISLAND
NARRAGANSETT BAY
BUZZARDS BAY
NEWPORT
NANTUCKET SOUND
VINEYARD SOUND
NEW LONDON
POINT JUDITH
WATCH HILL
MARTHAS VINEYARD ISLAND
NANTUCKET ISLAND
LONG ISLAND SOUND
BLOCK ISLAND
MONTAUK
0 5 10 15 20 25 30 35 MILES
COAST LINE NEW LONDON TO BOSTON
SHOWING PROPOSED CANAL ROUTES

another short divide and enters the head of Point Judith Pond, through which it passes south to a connection with a series of ponds extending westerly along the southern shore of Rhode Island from Point Judith nearly to Watch Hill. (This section comes nearer to fulfilling the description of "within a biscuit's throw of the ocean" than any of the others north of Beaufort, N. C.) From Watch Hill the line passes into Little Narragansett Bay; thence into Fisher's Island Sound and Long Island Sound at about New London. The Sound is followed to New York; from there the canal will be carried across New Jersey and enter the Delaware River somewhere near Trenton, descend the Delaware, passing Philadelphia, Chester, Wilmington, Del., to Delaware City; thence across the state of Delaware into Chesapeake Bay; thence to Norfolk, Va., where it enters the land and crosses to the North Carolina sounds back of Cape Hatteras, to Beaufort, N. C. South of Beaufort it extends along the coast line through rivers, ponds, and lagoons to Florida.

The whole route might be divided into three divisions, that south of Norfolk being the lumber and agricultural division; between Norfolk and New York the coal division, constituting the entire water frontage of the great coal states; and from New York to Boston, the marketing division for the natural products of the other two.

It is not alone as a regulator of rates that this canal is designed to afford the cheapest means of transportation, but it serves to afford an indispensable supplement to the railroads traversing the Atlantic coast section and other portions of the country that can be reached. In 1907 the transportation facilities of the country were taxed to their limit and so far over-burdened that freight blockades were occurring everywhere. The products of industry could not be moved. At that time that great master of transportation, James J. Hill, said that it was the greatest problem the country had before it. He estimated that it would require the expenditure of $1 100 000 000 annually for five years to put the railroads in condition to properly handle the freight then offered, and that such a proposition could not be financed, nor could the labor be obtained to execute the work required; and I have seen it stated in the daily papers that he anticipates a recurrence of the trouble, and has increased the estimate previously made. A

slight idea of the work involved might be gained by consideration of the work of the Pennsylvania Railroad Company Terminal in New York, which has been in progress some four or five years and involves an expenditure of something like $100 000 000. Mr. Hill's estimate calls for 55 similar operations annually. The railroads are utterly unable to handle the freight when the rush comes, and are restricted more by lack of terminals than lack of trackage. Mr. Hill stated, in regard to the difficulties of 1907:

"A common carrier has reached its limit when it is moving, at all times, over its system as many cars as can run upon its tracks with safety, and be transferred and dispatched from its terminals and junction points without unreasonable delay. Beyond a certain limit, the increase of business cannot be handled by increase of cars and engines. . . . No additions of equipment and no increase of efficiency of operation can take the place of the imperatively required new trackage and terminal facilities."

President Roosevelt, in appointing an Inland Waterway Commission, said, in 1907:

"It is common knowledge that the railroads of the United States are no longer able to move crops and manufactures rapidly enough to secure the prompt transaction of the business of the nation, and there is small prospect of immediate relief. . . . There appears to be one complete remedy, — the development of a complementary system of transportation by water."

The Hon. C. P. Goodyear, of Brunswick, Ga., a close student of the conditions attendant upon the freight blockade of 1907, said:

"I want to give reasons which seem to me controlling, why, in the future development of the country, reliance cannot be placed even in the increase of 2 per cent. hereafter in railroad mileage. The greatest average yearly increase in railway construction between 1880 and 1890 of 7 300 miles per year, with a population ranging from 50 000 000 to 63 000 000, is followed by a period from 1890 to 1907 with but 3 400 miles average increased mileage per year, with a population ranging from 63 000 000 to 86 000 000. . . . The reduced mileage per year in the later period is due to increased cost of railway construction, not so much on account of increased cost of material and equipment, motive power, and labor as because of the rapidly increasing cost of right of way, of terminals and station locations in towns and cities.

"With returning prosperity, which is sure to come in increased volume with growing population, the railroads will indeed be utterly inadequate to handle traffic, and, without a supplementary system of transportation, agriculture, mining, and industrial growth must be curtailed."

It is plainly the lesson of experience that the railroads are not able to handle the products of our industry in times of prosperity, and it is a clear duty, if we would continue to expand in our industrial growth, to prepare as rapidly as possible for future requirements in this line; and it is my aim to urge this upon your attention to the end that the popular recognition of the importance of the subject will compel action. Congress has recognized the importance of the subject to the extent of providing surveys for the various routes and directing the preparation of the estimate of cost, which work now is about completed. It is generally believed by those who have given the subject consideration that all of these waterways should be owned by the national government, and thereby preserve for the people a water highway free for the use of all who desire. While this view may be to some extent inspired by the tendency of the great transportation companies to monopolize the business, it must not be forgotten that these great concerns, with all their trained machinery for securing the freight, will be forced to make use of the waterways for themselves on account of the conditions which will be available, but they cannot have an exclusive right of way, which will always be available for the small concern as well as the large corporation. The result in either case will be a lowering of rates.

With regard to the importance of this great movement to New England, it is desirable to consider its situation with respect to the rest of the country. It is farther from the points of production of all the raw material which enters into the products of its mills than any other manufacturing section of the United States, and hence is more deeply interested in the cheapest possible form of transportation that can be devised, both for the raw material and marketing its product. The manufacturing industries have attained a strong position in the industrial world, based on a thorough development of the available water powers and upon the characteristic energy, intelligence, and enterprise of its citizens;

but the extent of the industries has far outgrown the power of the watersheds, and the lesson of careful management and operation has been learned by her rivals and is being more and more effectively applied in other localities with the enthusiasm which always accompanies successful development of new lines of work, so that the difference of the cost of the finished product is measured more nearly to-day than formerly by the distance between the points of production and consumption of the raw materials. As those elements of cost dependent upon mental qualifications and the results of long experience become equalized in the different sections of the country, transportation becomes more and more the ruling factor in the strife for industrial supremacy. Under existing conditions New England is seriously handicapped in matters of cheap water transportation by the difficulties and dangers of the passage around Cape Cod and Point Judith, together with the stretch of ocean navigation from Race Rock at the eastern end of Long Island Sound to the western entrance of Vineyard Sound.

In the course of the traditional repetition of history this great movement in the United States, looking towards the development of waterways both natural and artificial, to the end that better facilities may be afforded, has revived.

Before the advent of the railroad era and after the highways had reached their economical capacity, attention was turned towards transportation by canal, and between 1783 and the end of the eighteenth century charters were issued for companies which should construct the Dismal Swamp Canal southward from Norfolk, Va.; the Chesapeake and Delaware Canal, joining the waters of those bays; and the Delaware and Raritan Canal, leading to New York Harbor, thus giving a waterway from the North Carolina sounds to Long Island Sound, which, however, from the modern point of view was of very small capacity. In April, 1808, Albert Gallatin, Jefferson's Secretary of the Treasury, in response to a resolution of Congress, presented a comprehensive plan involving a continuous inland waterway along the Atlantic coast. The present movement is, therefore, but a revival of the projects then proposed and in part carried out, enlarged and adapted to present-day needs.

It was a part of the Gallatin plan that tributary small canals threading the interior should bring freight to the main waterway

along the coast. Among others, a number of small canals were built from the coal regions of Pennsylvania to tide water, and until they became the property of the railroads served a useful purpose; but they carry little if any coal to-day. Consider for a moment what it would mean to New England could those canals be rehabilitated and adapted to modern requirements, so that a barge could be loaded at the mines and be brought to your New England ports without a transfer. Consider what it would mean to the states of Connecticut, central Massachusetts, Vermont, and New Hampshire, to have an adequate waterway extending from Long Island Sound up the valley of the Connecticut River, even if its benefits were limited to a strip 50 miles wide on either side. Would there not be enormous possibilities in a protected waterway leading from New England ports by way of the Hudson River, the new barge canal across New York State and the Champlain canal to the Great Lakes and the valley of the St. Lawrence, bringing you into touch with millions of population, consumers of your products, upon which freight of about one mill per ton mile would be paid instead of about five mills, the average railroad rate of the present day? The time consumed in the deliveries of freight by the water route would be much shortened. The average rate of progress of a freight car is but twenty-five miles per day. A week is no unusual time to elapse between the shipment and delivery of freight by rail between Boston and New York. I am told that three or four days is common between Philadelphia and Baltimore. I have had personal experience of an interval of three months between Jersey City and Salt Lake City. Once on board a barge and started in the tow, there is no sidetracking or delay, but a steady pushing forward, at a slow rate perhaps, to destination.

It is not expected that an intra-coastal canal is going to do away with coastwise ocean traffic, for the steamers built for the trade will continue to ply up and down the coast, and the sailing vessels to beat along their old-time tracks; but bulky freight, such as coal, lumber, cotton, and many commodities destined for inland points, will be carried by suitable vessels by water. And one essential element of the success of this entire project consists in the development of the most efficient type of boat adapted to the minimum depths of water in the various branches of the canals

in the entire system or such portions of it as they are ever likely to use.

Due to the necessity of building the ocean vessel of sufficient strength to resist violent storms, her cost in the United States is about $71 per ton of freight carried. On the Great Lakes, vessels are subject to storms of less violence and the cost is about $41.50. A Mississippi steamboat and 10 barges capable of transporting 10 000 tons of freight on 8½ ft. of water can be built for about $12.50 per ton of freight carried. The modern sea-going tow of steel barges with their ocean-going tug, costing about $28 per ton, can be replaced on this proposed protected waterway by a type costing $17 per ton, and by it Providence is brought 140 miles nearer Philadelphia and 250 miles nearer Baltimore. With a rate of 75 cents per ton from Philadelphia to Providence by sea, — about the highest rate usually paid, — it is found that the same return on the capital investment will be yielded with a rate of 48.6 cents by a canal aside from any saving due to the elimination of the dangers of the ocean trip.

The feature of the efficient adaptation of the type of vessel to the traffic is strikingly exhibited in the lake traffic, where this system is highly developed, when last year the largest traffic was conducted with 20 per cent. of the tonnage out of commission, owing to improvements in handling freight (10 000 tons of ore loaded in thirty minutes, four to five hours in unloading).

To-day the eastern New England states cannot be reached by water without at least a short ocean trip. Upwards of 20 000 000 tons of freight pass the southern shore of Rhode Island annually, some coming around the eastern end of Long Island, but the great bulk coming out of Long Island Sound.

With the fall and winter storms comes the annual tale of disaster, especially to the towing fleet, and every year records the loss of a number of barges too often accompanied by loss of life; the sailing fleet is not exempt, and fog brings many a steamer with valuable cargo to the end of her career. With regard to the barges, the almost universal criticism is, " Why should the government permit the use of such vessels for an outside trip? " Regulations have been established by Congress looking to an amelioration of these conditions which went into effect January 1, 1909;

but with each additional restriction there is additional expense which is adding to the cost of your transportation. The inexpensive type of barge, called sometimes the "coffin barge," but more properly, I believe, the "box barge," now growing in use for the transportation of coal from New York to Narragansett Bay points, is a boon to that section but too light to come to Boston unless there should be a protected way. As it is now, they are frequently detained for periods of two weeks at New London awaiting a chance to get into Narragansett Bay. A short time ago I saw one that had taken thirty days to make the voyage from New York to Pawtucket.

The stretch of ocean navigation from Race Rock at the eastern end of Long Island Sound to the western entrance to Vineyard Sound, about sixty miles in length, is perhaps the scene of more marine disasters accompanied by serious loss of life and property than any like distance along the Atlantic coast, save that from Nantucket Sound to Provincetown. And this condition pertains not by reason of more severe storms and heavier fogs than elsewhere, although there is an abundance of both, but largely from the enormous traffic passing. This traffic is in a way congested, for in thick or foggy weather every vessel bound for Narragansett Bay is obliged to take her departure from Race Rock Light and run her prescribed course for a certain number of hours and minutes and find the Point Judith whistling buoy or she is in imminent danger; and the vessel bound out of the bay is obliged to take the same line from the whistling buoy for Race Rock. In the same way vessels bound to and from points east of Narragansett Bay are compelled to follow prescribed courses to find their turning points, and the two courses are quite close together. At the same time the sailing vessels, forming about 28 per cent. of the whole fleet, are beating across these courses in adverse winds. In addition to the Sound fleet there are those coming from southern ports around Montauk Point and to the eastward of Block Island, all converging on the Point Judith buoy and the Vineyard Sound Light Vessel, increasing the hazard of the navigation of these waters.

It is not alone the barges of light construction that meet with disaster, but the parting of hawsers of the large barges from the

Chesapeake and Delaware bays is of frequent occurrence. Under such circumstances, the barge adrift is either picked up, goes ashore, founders, or works out to sea and weathers the gale; the whole, even under the most favorable conditions, a serious, costly, and hazardous experience. As the route extends eastward, the Nantucket and Monomoy shoals are encountered and the dangers vastly increased.

A map prepared in the United States Engineer Office at Newport, a few years ago, gives the approximate location of 1 016 marine disasters which had occurred between Fisher's Island at the eastern end of Long Island Sound and Provincetown, from 1880 to 1903, and there were doubtless many others of which no record was available. Of the total number, 377, or 35 per cent., occurred west of Narragansett Bay, such is the index of the dangers attendant upon that short ocean voyage from Race Rock to Narragansett Bay, and, taken in connection with the frequent long detentions of whole tows of barges at New London for weeks at a time, awaiting a chance to round Point Judith, offers a strong reason for building that section of the Rhode Island canal within a biscuit's throw of the ocean.

ESTIMATED COST OF SEA-LEVEL CANAL BETWEEN NARRAGANSETT BAY AND LONG ISLAND SOUND.

Description.	Cost.
Canal 18 ft. depth of water, 125 ft. bottom width:	
Cost of construction	$11 945 000
Cost of annual maintenance, capitalized at 4 per cent	3 750 000
Total cost	$15 695 000
Canal 25 ft. depth of water, 200 ft. bottom width:	
Cost of construction	$24 370 000
Cost of annual maintenance, capitalized at 4 per cent	4 000 000
Total cost	$28 370 000

NOTE. — The 18-ft. canal would have a bottom width of 250 ft. in the approaches and in the ponds traversed; the 25-ft. canal would have a bottom width of 300 ft. in the approaches and in the ponds traversed.

ESTIMATED COST OF VARIOUS TYPES AND DIMENSIONS OF CANALS BETWEEN NARRAGANSETT BAY AND BOSTON.

Description.	Depth of Water. 18 Ft.	25 Ft.
Lock canal, 35-ft. summit, bottom width 200 ft.:		
Cost of construction, Taunton River to Hingham Harbor	$29 590 000	$40 047 000
Cost of annual maintenance, capitalized at 4 per cent	20 178 000	20 903 000
Total cost	$49 768 000	$60 950 000
Lock canal, 35-ft. summit, bottom width 125 ft.:		
Cost of construction, Taunton River to Hingham Harbor	$24 955 000	$32 470 000
Cost of annual maintenance, capitalized at 4 per cent	20 178 000	20 903 000
Total cost	$45 133 000	$53 373 000
Lock canal, 20-ft. summit, bottom width 200 ft.:		
Cost of construction, Taunton River to Plymouth Harbor	$20 570 000	$26 848 000
Cost of annual maintenance capitalized at 4 per cent	14 035 000	14 785 000
Total cost	$34 605 000	$41 633 000
Lock canal, 20-ft. summit, bottom width 125 ft.:		
Cost of construction, Taunton River to Plymouth Harbor	$17 453 000	$21 678 000
Cost of annual maintenance, capitalized at 4 per cent	14 035 000	14 785 000
Total cost	$31,488 000	$36 463 000
Sea-level canal, bottom width 200 ft.:		
Cost of construction, Taunton River to Plymouth Harbor	$35 696 000	$47 133 000
Cost of annual maintenance, capitalized at 4 per cent	11 035 000	11 835 000
Total cost	$46 731 000	$58 968 000

Sea-level canal, bottom width 125 ft.:		
Cost of construction, Taunton River to Plymouth Harbor	$28 429 000	$37 420 000
Cost of annual maintenance, capitalized at 4 per cent	11 035 000	11 835 000
Total cost	$39 464 000	$49 255 000

NOTE. — All river and harbor sections to have a bottom width of 300 ft.

DISCUSSION.

MR. T. G. HAZARD, JR. I would like to ask if it will be possible to keep the canal open during the ice season.

MR. PARRISH. That has been considered a good deal, and it is generally thought that the canal can be kept open at such times as the rivers are open; that is, that there would be no more likelihood of the canals freezing up than there would be, for instance, of the Providence River or Pawtucket River, although there might be a little delay on that account. But the facilities for getting through and running on schedule time, not having to wait on account of storms or fog, would enable the merchants during the fall months to stock up with coal before the winter season came on. There is very great detention now even in the short trip from Long Island Sound into Narragansett Bay, and that is vastly increased, of course, in the trip from Long Island Sound to Boston.

MR. FRANK L. FULLER. How would the lock canals be supplied with water?

MR. PARRISH. They would have to be supplied, I think, by pumping. I have not seen any of the details of the lock canals. The Rhode Island canal would be purely a sea-level canal. The state made a survey down through Brockton for a canal at one time, and it was proposed to pump from the sea level up, to supply the water in that way.

MR. FULLER. Wouldn't that be very expensive?

MR. PARRISH. Yes; I think probably it would be.

MR. A. S. NEGUS. I have been in the towing business a lot around Cape Cod, and also in Long Island Sound, and I have often thought that an inside passage, such as has been suggested, would

be of very great advantage. As the gentleman has said, there are a great many serious delays from storms and bad weather, particularly from the Little Gull down to the end of Cape Cod. It is very dangerous both for boats and for the barges. The barges always suffer, of course, the most. Oftentimes in bad weather it is very serious for them, and also for sailing vessels. I have been shipwrecked twice on Nantucket Shoals with tows, and if we had had the Pawtucket Canal or this other canal which has been described, it would have been a wonderful advantage, both in respect to time and safety. When these long tows pass down through outside, they are a danger to everything, and anything of the kind which is suggested I think would be of very great help.

PROTECTION OF NEW YORK'S WATER SUPPLY FROM POLLUTION DURING CONSTRUCTION WORK.

BY ANDREW J. PROVOST, JR., SANITARY EXPERT, BOARD OF WATER SUPPLY.

[*Read September 13, 1911.*]

The existing water supply for the boroughs of Manhattan and Bronx in the city of New York is furnished from reservoirs and lakes in the watersheds of the Croton, Bronx, and Byram rivers in the counties of Westchester, Putnam, and Dutchess, on the east side of the Hudson River. The aggregate supply drawn from these sources approximates 300 million gallons per day.

The additional supply of 500 million gallons per day, work for which is now advanced, is to be taken from the watersheds of the Esopus, Rondout, Schoharie, and Catskill creeks in the counties of Sullivan, Ulster, Greene, Schoharie, and Albany, on the west side of the Hudson. This is generally referred to as the "Catskill supply."

The work now being undertaken includes the construction of the Ashokan Reservoir, an impounding reservoir of about 127 thousand million gallons, located in the foothills of the Catskill Mountains back of the city of Kingston; the Kensico Reservoir, an equalizing reservoir of about 40 thousand million gallons capacity, formed by combining and enlarging the existing Kensico Reservoir and Rye Pond storage basins near Valhalla in Westchester County; the Hill View Reservoir, a distributing reservoir of about 900 million gallons, near Yonkers, just north of the New York City line; the Catskill aqueduct, a conduit about 92 miles in length between the Ashokan and Hill View reservoirs, with a depressed crossing under the Hudson River at Cornwall; and the distributing aqueduct, a conduit of about 27 miles in length, from Hill View Reservoir through Manhattan Island to Brooklyn and under the Narrows to its terminus at Silver Lake on Staten Island, with branch conduits in the boroughs of Brooklyn and Queens.

The estimated cost of the entire work, including development of the Rondout, Schoharie, and Catskill watersheds and the installation of the filtration plant not yet undertaken, is $162 000 000.

These constructions, involving the employment of many thousand alien laborers, presented sociological and sanitary problems that required careful consideration and study, particularly where the site of the works occupies watersheds of important potable supplies.

Early in its work the Board of Water Supply realized the importance of these matters and undertook their careful study.

In the first place, the communities through which the work passed required protection against infection by contagious and communicable diseases.

Second, the operations of the work being within or adjacent to numerous watersheds contributing surface water for public and private supplies, the reasonable protection of these supplies against pollution was imperative.

Finally, in order that the work might proceed effectively and without interruption, and for humanitarian reasons, it was essential that the health of the force be maintained and all possible preventable disease eliminated.

These questions on similar work have heretofore been largely overlooked or left to the discretion of local boards of health, which, as a rule, have not been active until unsanitary conditions became so acute as to attract attention by important outbreaks of disease.

Some attempt to control such conditions by legislative enactment has been made in Great Britain and elsewhere, but the board having control of the Catskill supply undertook to draft into the specifications of construction contracts conditions regulating sanitary conduct on the part of the contractors' employees, and they have endeavored to secure the observance of these by systematic inspection.

No similar specifications were available for use as a basis of action, and those which have been adopted on this work for the protection of the Croton supply, whose watershed is occupied by the new aqueduct for a distance of about twelve miles, are here quoted in part for purposes of general interest.

For works occupying less important watersheds other specifications somewhat less forceful have been drafted, and where the works are outside of watersheds the specifications are still more moderate.

The following requirements have been embodied in the specifications for constructing the aqueduct in the four principal contracts occupying the Croton shed where the work crosses Croton Lake and several of the tributary streams.

SANITARY PRECAUTIONS.

(Article XXXII.)

Sanitary Precautions.

Section 50. The contractor and his employees shall prevent nuisances in and about all camps and works; shall protect water courses, reservoirs, wells, and other sources of water supply, public or private, from pollution, contamination, or interference, and safeguard the public health, as may be directed from time to time by the constituted authorities of the state and city. The contractor shall summarily dismiss and shall not again engage, except with the written consent of the engineer, any employee who violates this section.

Inspection by Engineer. Sanitary Precautions to be Satisfactory. Compliance with Sanitary Regulations.

Section 51. The engineer shall have the right, in order to determine whether the requirements of this contract as to sanitary matters are being complied with, to enter and inspect any camp or building or any part of the works, and to cause any employees to be examined physically or medically or to be vaccinated or otherwise treated; also to inspect the drinking water and food supplied to the employees. The sanitary precautions, the care of the employees, the camps and all territory occupied by the contractor, shall at all times be satisfactory to the engineer. The contractor shall promptly and fully, and in every particular, comply with all orders and regulations in regard to these matters, including all sanitary and medical rules and regulations which may have been or may be promulgated from time to time. And to this end and to properly preserve the peace, the Board of Water Supply police shall have the right of access to the contractor's camps and quarters.

Quarters and Stables.

Section 52. The contractor shall provide suitable and satisfactory buildings for the housing, feeding, and sanitary necessities of the men, and suitable stabling for the animals employed upon the work. All buildings for these or kindred purposes shall be built only in accordance with approved drawings and specifications. All houses occupied by employees shall be thoroughly screened to exclude mosquitoes and flies. The quarters for the men shall be grouped in properly arranged camps. The contractor shall submit the locations proposed for his camps and buildings to the engineer for approval, and no buildings shall be erected until such approval shall have been obtained. Camps shall, if ordered, be enclosed by barbed wire or other approved fences not less than ten (10) feet high, with not more than two (2) entrances. Each camp and the grounds surrounding it in all directions shall be thoroughly illuminated by electric arc lamps or other acceptable lights. This illumination shall be maintained from sundown to sunrise every night during the occupation of the camp, unless otherwise ordered. Employees may, so far as practicable, be required to remain within camp when not at work.

Sanitary Conveniences and Disposal of Excreta. Attendants. Preventing Nuisances.

Section 53. Buildings for the sanitary necessities of all persons employed on the work, beginning with the first men employed to build camps or for other preliminary operations, shall be constructed and maintained by the contractor in the number, manner, and places ordered. All persons connected with the works shall be obliged to use these conveniences under penalty of discharge. Unless otherwise directed, the sanitaries shall be provided with water-tight removable receptables of suitable capacity. These receptacles, if used, shall not be allowed to overflow, but shall be removed, without spilling, at required intervals, their contents at once treated as directed, and then promptly taken to a designated place outside the watershed, and there disposed of as ordered. If incinerators be used, they shall be efficiently operated. The contractor shall provide a sufficient number of acceptable attendants to keep all sanitaries in satisfactory condition and compel employees to use them. The contractor shall rigorously prohibit the committing of nuisances within the tunnels, the aqueduct, or other completed or partially completed structure, or upon the land of the city about the works, or upon adjacent private property.

Medical and Surgical Attendance. Hospitals.

Section 54. The contractor shall retain the services of acceptable qualified medical and surgical practitioners, to the number ordered, who shall have the care of his employees, shall inspect their dwellings, the stables, and the sanitaries as often as required, and shall supply medical attendance and medicines to the employees whenever needed. The contractor shall provide, from approved plans, one or more buildings, properly fitted for the purposes of a hospital, with facilities for heating and ventilating in cold weather, and for screening and ventilating in warm weather. These hospitals shall have an ample number of beds to properly care for sick or injured employees, and shall be provided with all articles necessary for giving "first aid to the injured," as well as with all necessary medicines and medical appliances for the proper care for the sick and injured. Another building of approved design shall be provided and equipped as an isolation hospital, and any employee who shall be found to have a communicable disease shall be at once removed from the camp to this hospital, and there isolated and treated as directed. Whenever practicable, an employee having a communicable disease shall be removed, when and as directed, to a hospital outside the watershed.

Medical Supervision of Employees.

Section 55. The medical supervision of the contractor over his employees shall extend to the physical and medical examination of all applicants for employment, in order to prevent persons having communicable diseases from becoming connected with the work, and the contractor shall employ only persons shown by such examination to be free from communicable diseases. Whenever, in the opinion of the engineer, it is necessary for the protection of the public health or the health of the employees, the contractor shall remove any employee from the work either to a hospital at or near the works or to a more remote hospital, or shall remove permanently from the work or any camp any employee whose presence is believed to endanger the health of other persons.

Health Reports.

Section 56. Once each week, or more frequently if required, the contractor shall give the engineer, in such detail as may be prescribed from time to time, a written report, signed by the physician in regular attendance, setting forth clearly the health conditions of the camp or camps and of the employees. If any

case of communicable disease be discovered, or any case of doubtful diagnosis, it shall be reported at once to the engineer, by telephone or messenger, and confirmed in writing.

Domestic Water-Supply. Bath and Laundry Facilities.

Section 57. The water furnished by the contractor shall include a sufficient supply of drinking water of acceptable quality for all his employees, to be obtained from approved sources. He shall provide ample bathing and clothes-washing facilities for his employees and sufficient water of acceptable quality therefor. If any water supply for domestic uses should become contaminated, the contractor shall promptly provide a new supply from an approved source and abandon the contaminated supply, or shall provide works for purifying the contaminated water when and as ordered.

Disposal of Wash Water and Stable Drainage.

Section 58. All wash water from kitchens, laundries, and other places, and all drainage from stables, shall be conveyed by satisfactory means to places directed, where such drainage shall be treated by the means ordered so as to yield an acceptably innocuous effluent.

Drainage from Camps and Tunnels to be Filtered.

Section 59. Drainage from camps and tunnels and from other places yielding water unfit for direct discharge into a reservoir or tributary thereof shall be conducted in tight drains or other approved conveyors to filters, septic tanks or other disposal plants of approved construction, at places designated, and treated as directed to produce an acceptable effluent. Such effluent shall be discharged only in the manner and at the place or places directed.

Garbage Disposal.

Section 60. Garbage, both liquid and solid, shall be promptly and satisfactorily removed from the buildings and immediately placed in approved tight receptacles of sufficient capacity for about one day's ordinary production. At least once in every twenty-four hours all such garbage shall be incinerated or otherwise thoroughly and satisfactorily disposed of in an approved manner.

Contractor to Build Sanitary Works.

Section 61. The contractor shall build, in accordance with drawings and directions furnished from time to time by the engineer, such disposal plants, sewers, drains, and other structures, and shall do such other work, not herein particularly specified, as may be ordered for carrying out the intent of the sanitary precautions of this contract.

The five labor camps established for these contracts have a maximum population of about 1 500. The sites are in all cases located on property leased by the contractors after most careful study in which consideration was given to exposure, drainage, accessibility to the work, including sanitary transportation of the men to and from the camps, and protection against pollution of the lake and streams from the camps themselves with available precautions. Some of these precautions are:

The prompt incineration of all human discharges.

The collection and treatment of all liquid camp wastes from kitchens, laundries, lavatories, etc.

The collection and treatment of all storm water falling within the camp areas.

The collection and prompt destruction of all garbage and stable manure.

The physical examination of all applicants for employment and their careful medical observation while in camp or on the work.

The prosecution and punishment of persons committing nuisances.

The enclosing of camp areas by man-proof fences.

The illumination of camp grounds.

General precautions for maintaining the health of the force by supplying adequate and suitable housings, supplies of pure drinking water, hospitals for treatment and isolation and constant medical attendance.

INCINERATION.

The incineration of human wastes has been accomplished usually in apparatus adopted by the United States Army since 1907 for

its encampments, in which the material is evaporated in a sheet-iron receptacle having from one to four seats. This process is effective, but in the hands of cheap labor, such as is usually employed, the record of absence from odors does not compare favorably with army practice. Moreover, the apparatus, being originally designed to be portable, is too light for continuous hard driving under ignorant or careless management. The charges for repairs and renewals have in some cases been so burdensome that modified furnaces have been designed and constructed by some of the contractors to overcome this objection. Experience on the whole has shown it is entirely feasible to properly and economically dispose of human wastes in this manner, and that the results outweigh complaints of odors which at times arise.

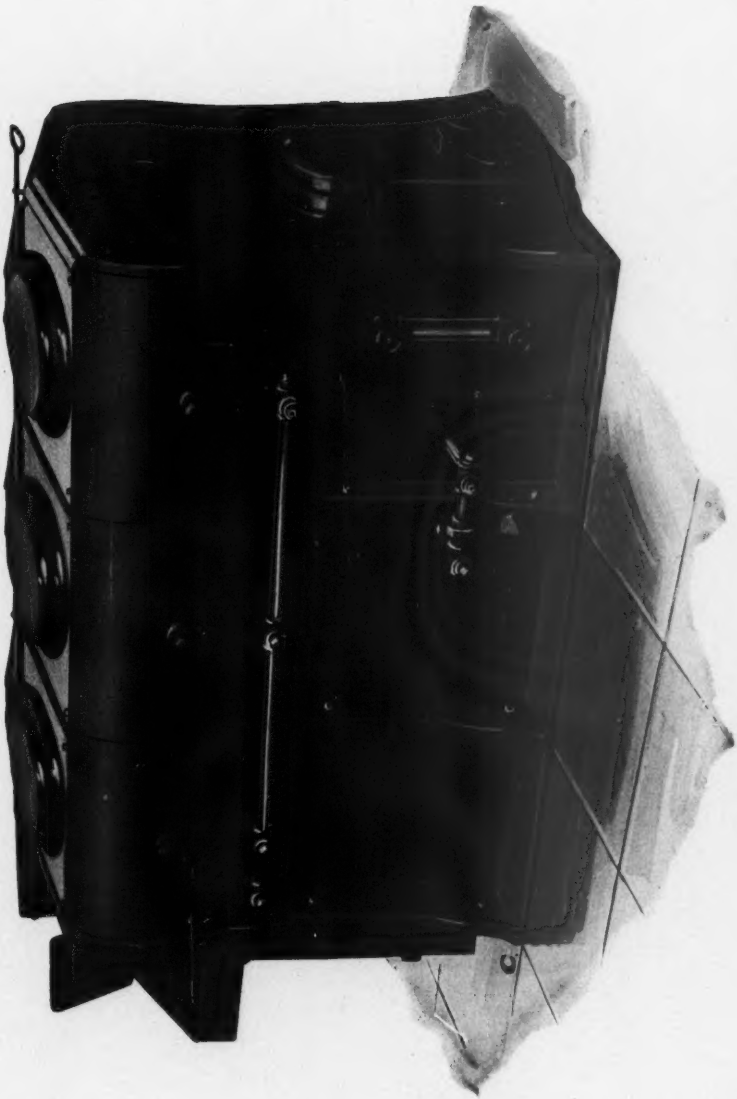
LIQUID CAMP WASTES.

Liquid camp wastes from plumbing fixtures, such as sinks, tubs, showers, lavatories, etc., are collected in a system of sewer pipes, passed through a grease trap and settling tank, thence through a sand filter and are finally treated with hypochlorite of calcium solution before being discharged into a water course.

STORM WATER RUN-OFF.

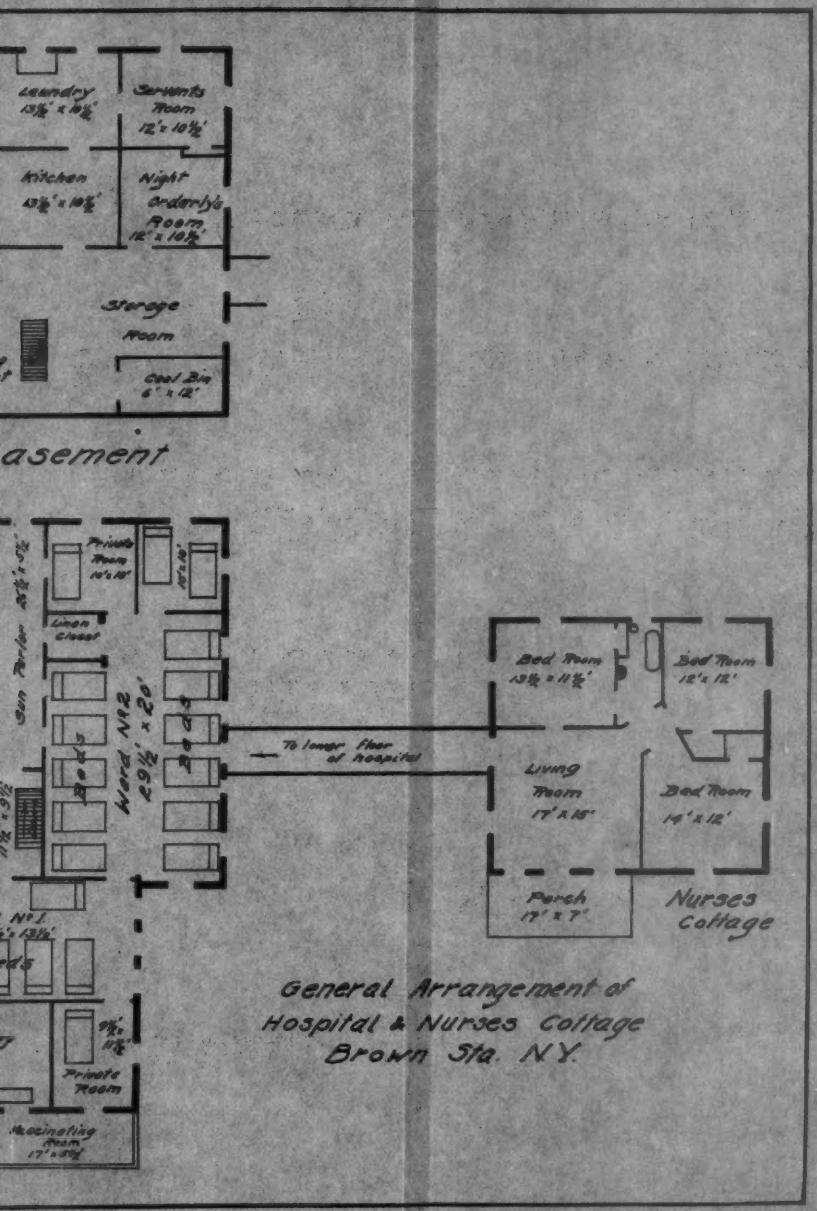
All rain water falling outside of the man-proof fence is diverted by suitable ditches. That falling within is collected in open trenches and culverts and delivered to a sedimentation basin with earth banks and floor, having storage capacity for run-off proportional to the size of the camp. The outflow from these basins passes to two or more sand filter units designed to take 2½ million gallons per acre per day without negative head. The capacity of the sedimentation basin, together with the designed rate of filtration, is as a rule about .8 of Talbot's curve for run-off from long heavy rainfalls. The filtrate is automatically treated with hypochlorite solution in proportion to the flow, and in some cases it is thereafter held for a short period in a timber retention basin before being permitted to enter a water course.

PLATE 1.
N. E. W. W. ASSOCIATION,
SEPTEMBER, 1911.
PROVOST ON
PROTECTION OF NEW YORK'S WATER SUPPLY.



TYPICAL EVAPORATIVE FURNACE FOR INCINERATION OF HUMAN WASTES.

Carriage House
20' x 11'
Horse Stall
11' x 9½'
Morgue
Heating Plant
Bas
Diet Kitchen
11½ x 9½'
Bath Room
Operating Room
13½' x 9½'
Etherizing Room
13½' x 9½'
13½' x 9½'
Doctors Office
11½' x 9½'
Waiting Room
Dispensary
10' x 11½'



General Arrangement of
Hospital & Nurses Cottage
Brown Sta. N.Y.

GARBAGE AND MANURE.

Garbage is collected in approved covered cans and daily removed to a pit having a central masonry cone and there destroyed by combustion.

Stable manure is not permitted to accumulate but is collected daily and either burned or disposed of for fertilizing purposes.

MEDICAL.

Each camp has a medical officer always on call, whose duty it is to physically examine all applicants for work and to vaccinate all persons admitted to the camps and works. The certificate of vaccination issued by him to an applicant is good on all Board of Water Supply work for one year. The physician is also required to provide medicine for and to treat all camp inmates and laborers needing medical and surgical aid. Each camp hospital contains a dispensary, an operating room, a bath, a room for nurse or orderly, and a ward with beds for two per cent. of the force and 600 cu. ft. of space for each bed. There is also a small detention ward for temporary isolation and observation purposes. The entire building is steam heated and lighted by electricity. It is the physician's further duty to supervise all sanitary works and to enforce the observance of sanitary regulations. He is required to present a weekly health report, giving the camp population, the names and addresses of all employees residing out of camp (these include as a rule only the higher grades of labor), an itemized statement of surgical and medical cases, with transfers and deaths, the number of persons admitted to camp and works, the number admitted by vaccination or certificate, also the sanitary and health conditions of camp and employees at the date of the report.

The presence of the force of aqueduct police along the line of the work is of very great assistance in enforcing sanitary conduct and in effecting rigid isolation and quarantine when required.

CAMP BUILDINGS.

Previous to the construction of the camp the contractor is required to submit a layout plan indicating the number, character,

and arrangement of the buildings to be erected, together with detailed plans of all structures. These include dormitories, mess halls and kitchens, wash houses for laundry and lavatory purposes, hospitals for treatment and isolation, stables, sanitaries or toilet buildings, etc. All buildings are detached, having light on four sides and sufficiently close to produce a compact camp without crowding.

The dormitories are, as a rule, one-story structures with a central corridor extending the entire length thereof, with rooms for two or four men opening from it. One recreation or lounging room is usually provided in each building. The interior partitions are usually dwarfed, terminating at the plate line with wire netting or slats above this line to the roof, on the peak of which one or more louvered ventilators are placed, according to the length of the building. Each inmate is provided with a separate bed, bunk, or cot, and has 400 cu. ft. of space. The window area is about 3 sq. ft. per person, and the vent area is about $\frac{1}{3}$ sq. ft. per person. The buildings are heated by stoves or steam coils, and are usually lighted by electricity. The inmates are expected to keep their rooms clean, while a cleaning gang attends to the corridors and lounging rooms. No eating or storage of foods is permittted in the dormitory buildings. The mess halls and kitchens are in separate rooms, and are suitably ventilated and screened. Where bake ovens are provided for Italian labor, they are housed to give shelter and to facilitate cleaning.

The wash houses have concrete floors and are provided with laundry tubs, hand basins, and shower baths.

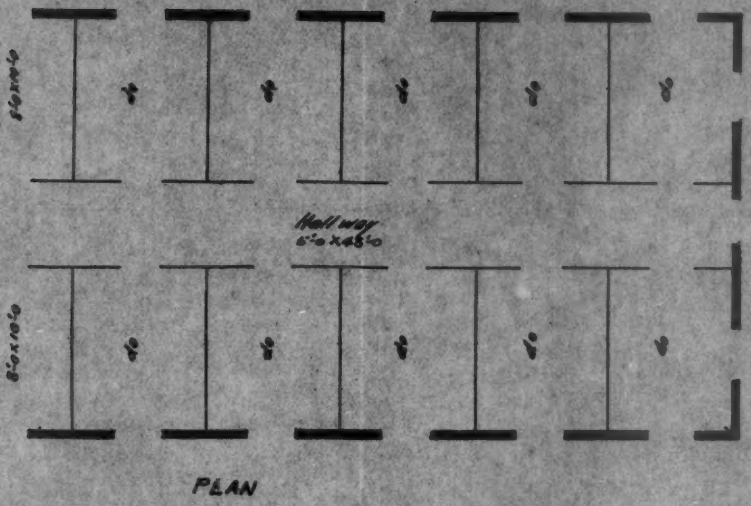
The treatment and surgical hospital has already been described. The isolation hospital is a simple building with ward space, 600 cu. ft. for one per cent. of the force, together with a kitchen and bed-room for nurse or orderly. This building is surrounded by a man-proof fence, for purposes of quarantine during sickness and convalescence.

The stables have concrete or other non-absorbent floors which are suitably drained. With respect to size and ventilation they are carefully designed and compare favorably with the other camp buildings.

The sanitaries have concrete floors and screened window, door,

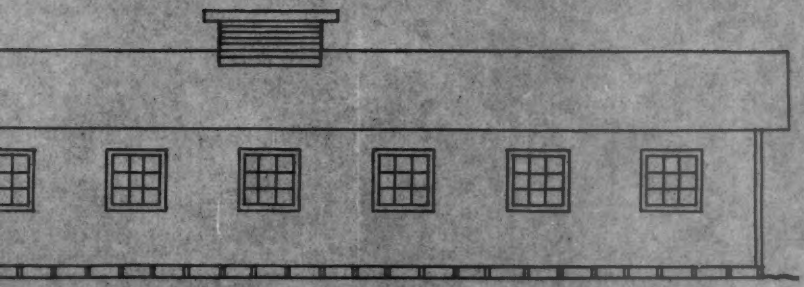
Bedroom
Bedroom
Lounge and Dining Room
23'0 x 22'6
WORK
KEY

PLATE III.
N. E. W. W. ASSOCIATION,
SEPTEMBER, 1911.
PROVISO ON
PROTECTION OF NEW YORK'S WATER SUPPLY.



PLAN

ORKMANS DWELLING FOR 24 INMATES
CONTRACT 30
EYSTONE STATE CONSTRUCTION CO.
SCALE OF FEET



SIDE ELEVATION

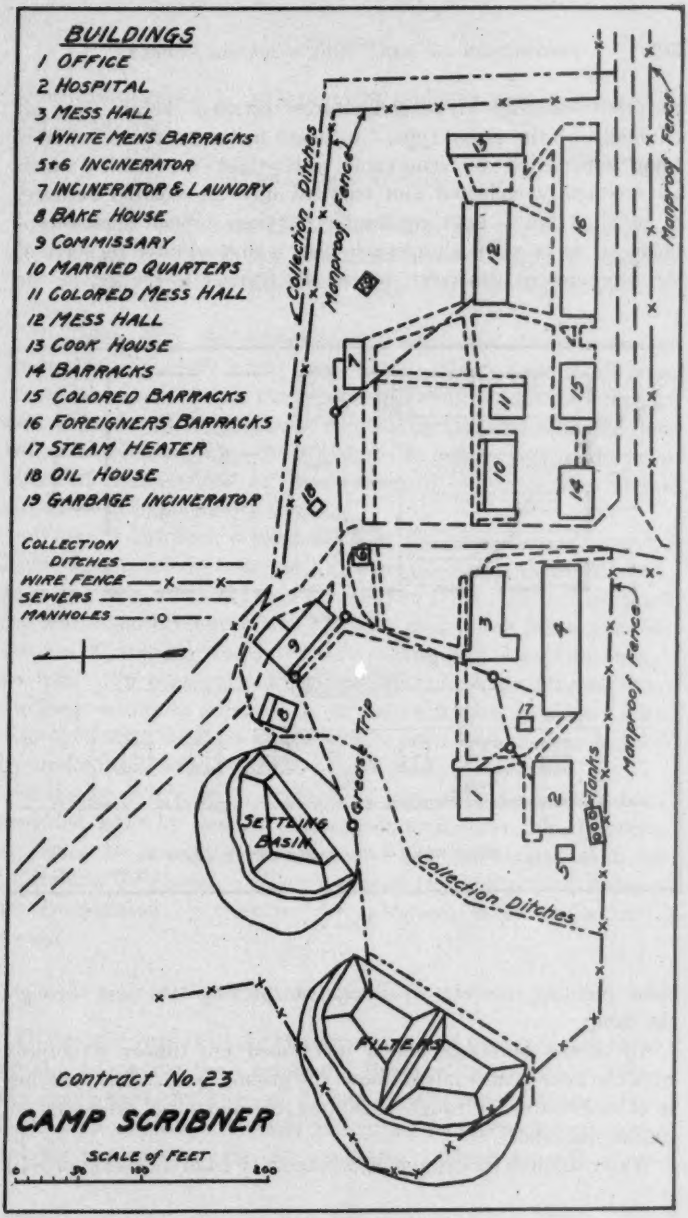

BUILDINGS
1 OFFICE
2 HOSPITAL
3 MESS HALL
4 WHITE MENS BARRACKS
5+6 INCINERATOR
7 INCINERATOR & LAUNDRY
8 BAKE HOUSE
9 COMMISSARY
10 MARRIED QUARTERS
11 COLORED MESS HALL
12 MESS HALL
13 COOK HOUSE
14 BARRACKS
15 COLORED BARRACKS
16 FOREIGNERS BARRACKS
17 STEAM HEATER
18 OIL HOUSE
19 GARBAGE INCINERATOR
COLLECTION DITCHES
WIRE FENCE
SEWERS
MANHOLES
Collection Ditches
Manproof Fence
Grease Trap
SETTLING BASIN
FILTERS
Collection Ditches
Manproof Fence
Manproof Fence
Contract No. 23
CAMP SCRIBNER
SCALE of FEET
0
50
100
200

FIG. 1.

and vent openings. The incinerators installed therein were all originally of the army type. In some instances these are now being superseded by removable water-tight receptacles which are frequently collected and emptied into an isolated furnace, in which a fire is kept constantly burning. When such receptacles are to be used, a preferable plan is that adopted on some of the more recent contracts, where the furnace is housed in the

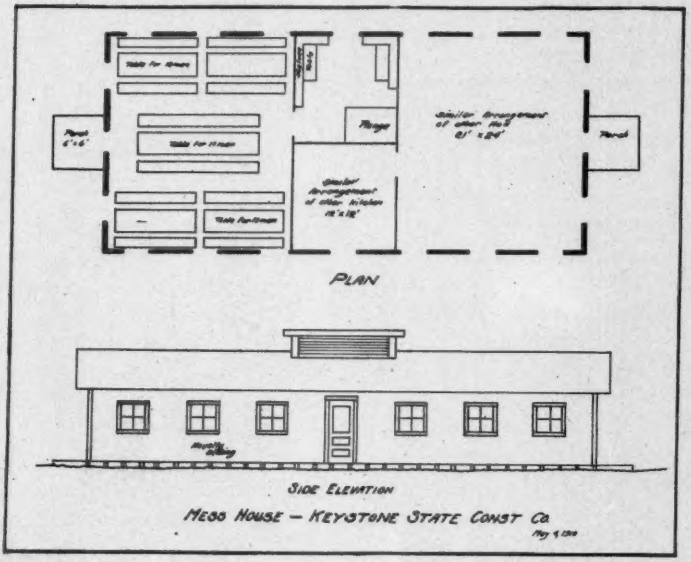


FIG. 2.

same building, thereby avoiding transporting the cans through the camp.

All of the buildings herein mentioned are timber structures with the floor beams raised above the ground level. The covering is of clapboards or rough sheathing covered with rubberoid or similar material.

Water supplies for camp purposes must be from sources approved

after careful analysis. It is provided under pressure from suitable storage tanks.

SPECIAL PRECAUTIONS.

Incinerator plants are located at shafts and portals and along the line of the works, or else portable water-tight receptacles are provided and brought into camp daily for incineration of contents.

Realizing that the undetected commission of nuisances is more likely to occur in the tunnels than above ground, all mine water as well as the rain wash from spoil banks is collected, filtered and treated with hypochlorite solution in proportion to the flow before allowed to enter the streams. In some cases it has been found more convenient to treat constantly the entire flow of the stream with hypochlorite solution.

Where it has been possible without too great inconvenience to locate a camp off the watershed, this precaution has been followed, as in the case of labor camp for Kensico Dam. In this contract the additional precaution was taken to prohibit so far as possible the use of animals where traction engines and machinery could be used. In connection with this contract, some fifty to sixty dwellings within or adjacent to the future flooded area have been destroyed after purchase by the city in order that their occupancy by undesirable tenants might be effectively prevented.

A system of laboratory diagnosis of important diseases has been provided whereby samples of sputum, membrane, blood, faeces, etc., may be promptly examined and effective means taken for controlling the disease. Where messages relating to these diseases are transmitted by telephone or telegraph, a prescribed code is used.

RESULTS.

During the year 1910 the average number of workmen and camp inmates occupying the Croton and Bronx watersheds was 2 365. The death-rate, exclusive of violent deaths, was 4.4 per 1 000. There were no cases of typhoid among the contractor's employees, and but one case among camp inmates. These records corre-

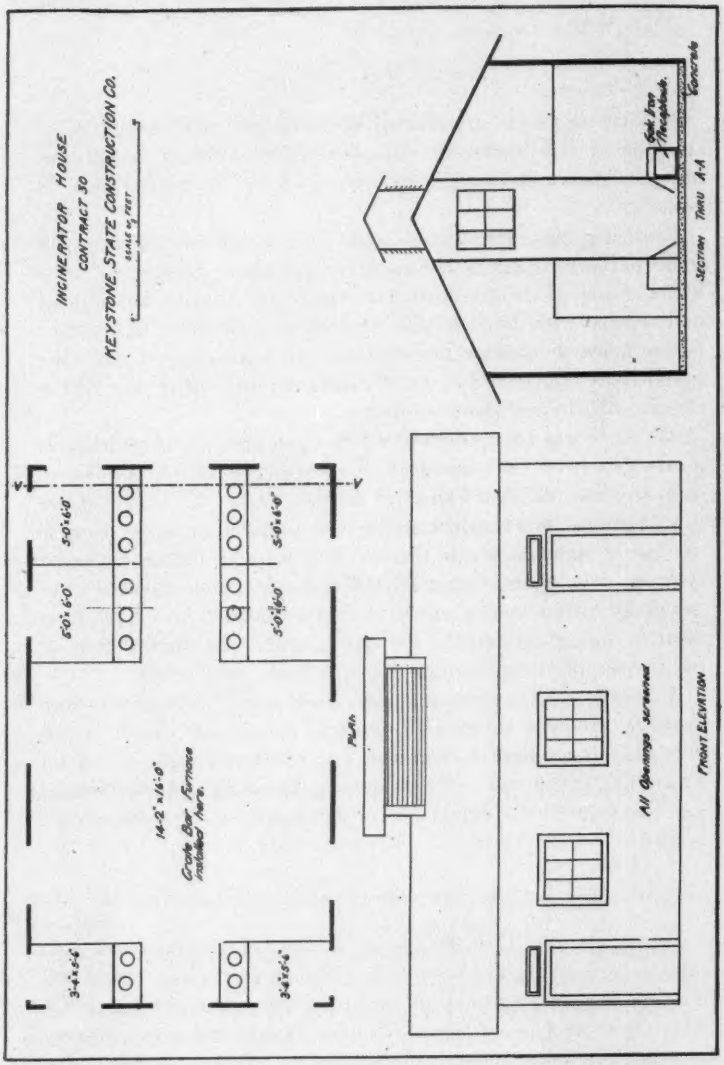

INCINERATOR HOUSE
CONTRACT 30
KEYSTONE STATE CONSTRUCTION Co.
SCALE 1/8" = 1 FOOT
5'-0"x6'-0"
5'-0"x6'-0"
14'-2"x16'-0"
Grate Bar Furnace installed here.
3'-4"x5'-6"
3'-4"x5'-6"
PLAN
All Openings screened
FRONT ELEVATION
Cast Iron Receptacle.
Concrete
SECTION THRU A-A

FIG. 3.

spond substantially with statistical results from about 15 000 employees on the entire line of work.

The expense of carrying out this great plan of sanitation and preventive medicine has necessarily been large, and it is hoped the final results will fully justify the expenditure and effort. If such be the case, the future problems that engineers and contractors on large isolated construction work must consider will include similar precautions and observances. If it is worth what it costs, it must gradually become general practice, and in order that its application may not be unfair or burdensome, the contractor must be furnished, before presenting his bid, with definite and specific information regarding the nature and extent of the duties and obligations to be imposed on him.

Each enterprise will present its own peculiar conditions, and these will have to be carefully thought out in advance. The mere formulation of sanitary rules and regulations will ordinarily be entirely ineffective unless provision is made for their enforcement by painstaking inspection. Trained men of suitable temperament are required for this work.

The application of the essential features described in this paper are not confined to municipal or governmental contract work, but apply as readily to mining, lumber, railroad, and recreation camps, expositions, and military and religious encampments and other places where numerous people are required to be housed and maintained in temporary quarters. Previous history shows that wherever attempt has been made to congregate the habitations of more than a very limited number of human beings or animals, there results a natural tendency toward destruction of the colony by its own discharges and waste products. This tendency is largely controlled by the introduction of suitable sewerage under proper conditions, but where sewerage systems could not or have not been installed, as in temporary encampments, such as have been mentioned, history records in substantially all instances the general prevalence of fever and pestilence, diseases now considered unnecessary and preventable. Investigation made subsequent to the Spanish War showed that more than 90 per cent. of the United States volunteer regiments developed typhoid fever within eight weeks after going into camp, and that about one fifth of the soldiers

in the national encampments contracted typhoid fever, and that the mortality from this disease amounted to more than 86 per cent. of all the fatalities.

Within the past few years, however, it has been conclusively shown that these results are entirely unnecessary and that with suitable precaution temporary encampments can be maintained without prevalence of disease exceeding that of the best-regulated cities and towns.

THE HUDSON RIVER CROSSING OF THE CATSKILL AQUEDUCT.

BY ROBERT RIDGWAY, DEPARTMENT ENGINEER, BOARD OF WATER SUPPLY, CITY OF NEW YORK.

[*Read September 13, 1911.*]

It is generally known that the city of New York is going to the Catskill Mountains for an additional supply of water and that construction work on the project is well advanced towards completion. The source of this supply and the point of distribution being on opposite sides of the Hudson River, that tidal stream must be crossed by the great aqueduct of 500 million gallons daily capacity that is to bring the water to the city.

Not only has the problem of the river crossing engaged the earnest attention of the engineers of the board, but it has attracted the notice of the general public as well. In fact, the latter has probably shown more interest in it than in any other engineering feature of the board's work.

The purpose of this paper is to describe in a general way the problem and the field studies which determined the location of the crossing, as well as some features of the construction. It is not intended to go into the details of the several phases of the work, as the scope of the paper will not permit it. A detail description of the field work is admirably presented in a paper entitled "Studies and Explorations for the Hudson River Crossing of the Catskill Aqueduct," prepared by Messrs. Samuel D. Dodge and William B. Hoke, Assistant Engineers, Board of Water Supply, for the Municipal Engineers of the City of New York, and published in the 1910 Proceedings of that society. The details of design of tunnels of the type adopted for the Hudson River crossing are described in a paper entitled "The Design of Pressure Tunnels of the Catskill Aqueduct," by Mr. Thomas H. Wiggin, Senior Designing Engineer, Board of Water Supply, and published in the 1909 Proceedings of the same society.

The Board of Water Supply, which is charged by Chapter 724 of the Laws of 1905 with the duty of securing the much-needed additional supply of " pure and wholesome " water, was organized in the summer of that year, and in the following autumn, on the recommendation of its chief engineer, Mr. J. Waldo Smith, a vice-president of this Association, decided on the Catskill sources.

The general plan, briefly stated, was to develop the watersheds of Esopus, Rondout, Schoharie, and Catskill creeks in the order named, together with a number of smaller sheds adjacent to them; to build an aqueduct of 500 million gallons daily capacity from the Esopus Creek to a distributing reservoir at Hill View near the city line; a storage reservoir of 40 000 million gallons capacity near Valhalla, 14 miles north of Hill View, known as the Kensico Reservoir; and trunk conduits to the boroughs of the Bronx, Brooklyn, Queens, and Richmond.

The importance of the river crossing was early realized. In his report to the board of October 7, 1905, the chief engineer referred to it in this language:

" The crossing of the Hudson River by the 500-million-gallon aqueduct is one of the most important matters for immediate consideration, and borings were begun recently to determine the character of substrata at the point where the surface indications give the greatest promise of favorable conditions. The work of boring is now in progress.

" Studies on the surface of the ground have indicated that it will be feasible to locate this crossing near the village of New Hamburg, as shown by the accompanying map.

" Either one of several types of river crossing may be made, according to the character of the bed of the river revealed by the borings."

The type of structure to be used for the crossing was given early consideration. Among other types so considered were:

1. A bridge at or below hydraulic gradient. The height of such a bridge was limited by the hydraulic gradient, about 410 ft. above the river, and the clearance which would be demanded by the War Department, probably 135 ft. above high water. Unless a pier was permitted in the channel, the span of the bridge would be at least 2 000 ft. at the narrowest location considered.

2. Steel or cast-iron pipes laid in the bed of the stream. Several lines of the largest practicable sizes would be required, both to obtain the necessary capacity and to insure safety. The latter consideration would also demand that the several lines be laid a reasonable distance apart so that if one should break under the high-service pressure it would not injure the others.

3. One or more tunnels driven by use of compressed air through the mud of the river bottom. The depth of such tunnels would be limited by the pressure under which the men constructing them could work, — not much over 100 ft. below tide. This construction would require a location where the depth of water was such as to provide a natural or permit an artificial covering for the tunnel during the driving of the latter. The ordinary cast-iron lining employed for transportation tunnels of this type of construction would not be sufficient against the enormous bursting pressure of the aqueduct tunnel. If such a lining was needed as a means of construction, an additional inner lining of steel would be necessary before putting the aqueduct in service.

4. A tunnel deep enough in sound rock to be secure against a break from internal pressure, lined with masonry to provide better hydraulic properties, and made tight against outward leakage through seams which might exist in the rock.

After careful consideration the rock tunnel type was early decided on for reasons of safety, durability, and economy. This type has come to be known as a " pressure tunnel," and is so called on the Catskill work to distinguish it from tunnels located on the hydraulic gradient, which are known as " grade tunnels."

With the question of type thus decided, efforts were directed towards finding the best location for the river crossing. It should be remembered that in determining the location, weight had to be given to the land approaches as well as to the river crossing itself; for instance, the advantages of a certain crossing might be apparent when considered by itself, but the land construction leading to it might be so expensive or otherwise objectionable as to destroy these advantages. This is made clear when it is realized that the extreme locations seriously considered for the crossing were 22 miles apart, and that a change from one extreme

to the other would affect the location of more than 40 miles of aqueduct.

In search of the crossing the river was studied from Pegg's Point, 2½ miles north of New Hamburg, to Anthony's Nose, in the lower part of the Highlands. A preliminary study showed that any crossing north or south of these points would mean a lengthening of the total line of the aqueduct, and consequently greater expense in construction and maintenance, without compensating advantages. (See Fig. 1.)

The lines considered as the most favorable ones formed themselves into two distinct groups, called for convenience the "New Hamburg group" and the "Highland group." The former included as its most desirable routes those crossing at Pegg's Point, New Hamburg, and Danskammer Point, and similarly the Highland group included the Plum Point, Storm King, Little Stony Point, West Point, and Anthony's Nose routes, so called from the localities where they crossed the river. Between the two groups mentioned the topography did not lend itself to a favorable crossing. The river was broader, reaching a maximum width of more than 1½ miles in Newburgh Bay, and the land approaches were not so favorable as those north and south of this gap.

The first general route for the Catskill Aqueduct, laid down tentatively in 1905, contemplated that the water would be drawn from the east end of the Ashokan Reservoir, in the Esopus watershed, near West Hurley. This brought the New Hamburg group into prominence, as a crossing in their vicinity would mean a far more direct line than would any crossing in the Highlands. This advantage of the New Hamburg group disappeared to some extent when further studies in more detail showed the advisability of locating the headworks of the aqueduct near Brown's Station at the dividing wall between the two basins of the reservoir. In addition, subsurface explorations made in the meantime for the pressure tunnel crossings of the Rondout and Wallkill valleys indicated better geological conditions farther upstream than at the crossings first proposed. Similar explorations in the valley of Fishkill Creek on the east side of the Hudson showed the presence there of a zone of disintegrated limestone extending to a great depth, which it would be advisable to avoid with a pressure

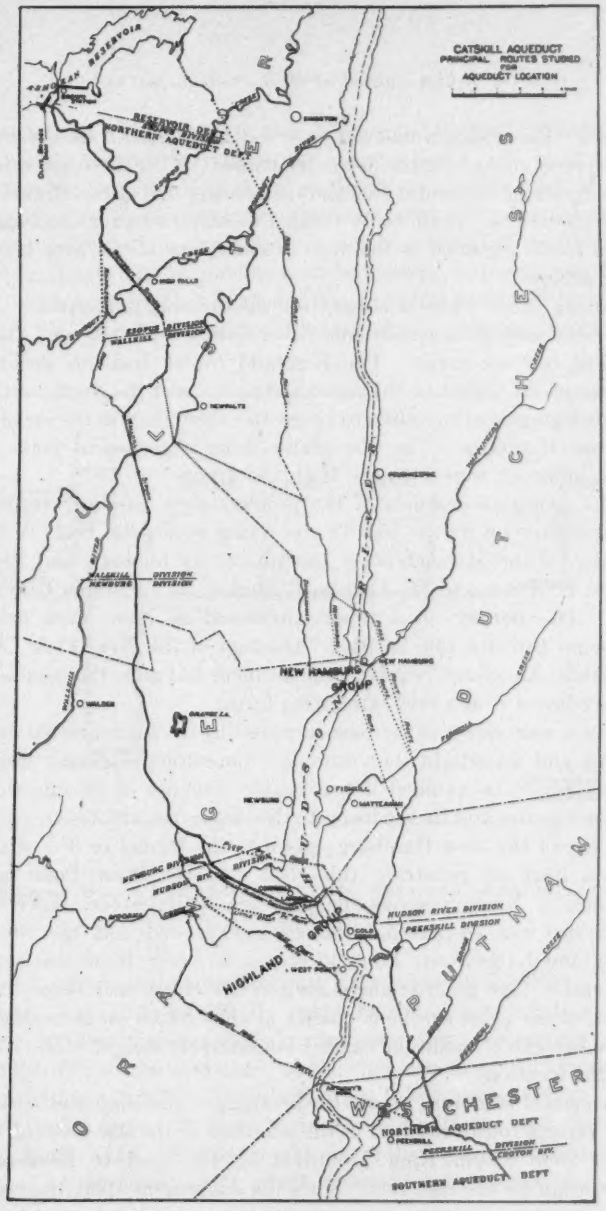


FIG. 1.

PRINCIPAL ROUTES STUDIED FOR CATSKILL AQUEDUCT, NORTHERN AQUEDUCT DEPARTMENT.

tunnel. This valley would not have to be traversed if the crossing of the river could be made in the Highlands. With these and other considerations in mind it was shown that any one of the Highland routes would be substantially cheaper to construct than the Pegg's Point route, regarded as the most desirable one of the New Hamburg group.

Among other features sought for the crossing proper were, (1) favorable geological conditions, (2) a narrow channel, and (3) a shallow bedrock gorge. The Highland routes had no decided advantage in regard to the narrow channel, and the depth of the bedrock gorge was supposed to be greater there than in the vicinity of New Hamburg. The advantages from a geological point of view, however, were with the Highland group.

The geological features of the problem were carefully studied and reported on by the board's consulting geologists, Prof. W. O. Crosby, of the Massachusetts Institute of Technology, and Prof. James F. Kemp and Dr. Charles P. Berkey, of Columbia University. Dr. Berkey, in a report published as New York State Museum Bulletin 146, entitled "Geology of the New York City (Catskill) Aqueduct," explains the problem and gives the results of his studies of it in a very interesting form.

It was essential that the rock surrounding the tunnel be not only strong and watertight, but durable. Limestone especially was a formation to be avoided if practicable, because of its uncertain characteristics and its tendency to develop caves and fissures. At any one of the New Hamburg crossings the tunnel or the shafts would have to penetrate this rock. At the West Point and Anthony's Nose crossings the presence of limestone under the river bed was suspected, although not proved. At the Storm King and Little Stony Point locations, however, there was every indication that granitic gneiss formed the entire rock floor of the river, of the same excellent quality as that found on both shores. This favorable condition carried considerable weight in deciding on the location.

A careful summing up of the advantages and disadvantages of the various routes resulted in the adoption of the line crossing the river from Storm King Mountain on the west to Breakneck Mountain on the east side. Since the summer of 1906, therefore,

work has been in progress at this crossing and its land connections, preparing for and carrying on the construction.

The Hudson River crossing, as finally located, is part of one long inverted siphon extending from the point where the aqueduct leaves the hydraulic gradient at the downtake shaft of the Moodna siphon, nearly 5 miles northwest of the crossing, to the uptake shaft on the slope on Breakneck Mountain, about 800 ft. east of the crossing. (See Fig. 2.) The total length of this pressure section of

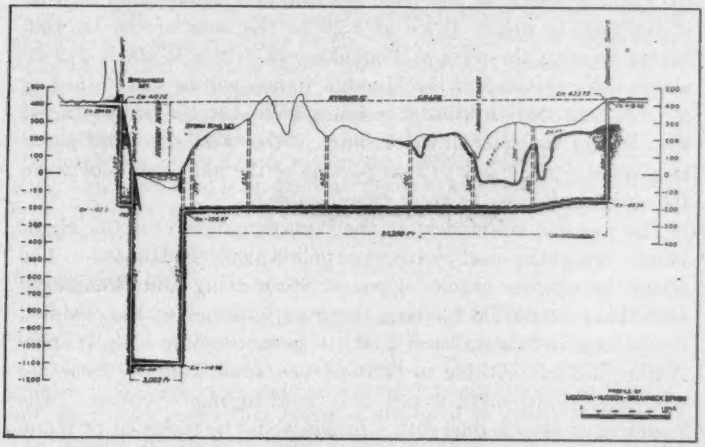


FIG. 2.

PROFILE OF MOODNA-HUDSON-BREAKNECK PRESSURE TUNNEL, CATSKILL AQUEDUCT.

tunnel, including the river crossing, is 29 015 ft., or 5.5 miles. The downtake shaft drops 594 ft. below hydraulic gradient to elevation −160.34. The tunnel descends thence on grades varying from −2% to 0% to the west shaft of the river crossing, which it meets at elevation −228.72. This shaft drops to elevation −1111. The river tunnel drops 3 ft. more to its junction with the east shaft to elevation −1114. The water will rise in the east shaft to the land tunnel at elevation −192, which is level to the uptake shaft on

Breakneck, and will rise in the latter 602.22 ft. to hydraulic grade. The tunnel elevations here given refer to the invert grades. It should be noted in passing that all the levels of the Board of Water Supply are referred to the datum plane of the United States Coast and Geodetic Survey, which is mean sea level at Sandy Hook. All of the permanent shafts of the tunnels, are circular. The Moodna tunnel and downtake shaft will be finished 14 ft. 2 in. in diameter; the other shafts and tunnel, 14 ft. in diameter. The tunnel and permanent shafts will be lined with concrete. The hydraulic gradient at the river crossing is approximately 410 ft. above tide, or nearly twice as high as the floor of the railroad bridge crossing the river at Poughkeepsie, which is about 212 ft. above tide. Shaft 7 of the Moodna siphon will be maintained as a permanent shaft so that access may be had to the tunnel on the west side of the river in the vicinity of the crossing. This paper is devoted particularly to that portion of the long siphon between the river shafts, or the river crossing itself.

The location selected is at the "north gateway of the Highlands," one of the most picturesque points along the Hudson. The almost precipitous granite slopes of Storm King and Breakneck, each rising over 1 200 ft. above the river, encroach on the channel, contracting it to a width of 2 800 ft. between shore lines. There Nature has left nothing to be improved upon, and any structure that man could build would only tend to mar the spot. The spanning of the channel with a bridge would be regarded by many almost as a sacrilege.

On the line selected the rock outcrops down to the water's edge. The river reaches a maximum depth of 85 ft. about one third of the way out from the west shore. The ordinary tides have a range of nearly 3 ft., the mean level being from 0.75 ft. to 2.25 ft. above mean sea level, depending on the season of the year and the flow of fresh water from above. The water is comparatively fresh in the spring of the year when the river's tributaries are flowing full. At such times it is available for boiler use. As the season advances and the supply of fresh water diminishes, the salt water is carried farther and farther up the river with the tides and the water becomes brackish, particularly at flood tide. Analysis of a sample taken at flood tide on August 15, 1911, showed 1 380 parts per

million of chlorine and 2 978 parts total solids, while a sample taken June 12, 1911, at end of the ebb tide showed 14.5 parts chlorine and 111 parts total solids.

Dr. Berkey in the bulletin mentioned refers to the Storm King location as follows, on page 104:

"This is wholly in massive and gneissoid granite. The rock is the most massive and substantial body of uniform type found in the Highlands. The course of the river indicates some weakness in that direction. This weakness may be some minor crushed zone or even the jointing alone that prevails throughout the exposed cliffs. But there is no direct evidence of faulting, cutting the line, and such crushing as may be encountered is believed to have originated at such depth and under such conditions as to cause no large disturbance. The freedom of this formation from all bedding structures and natural courses of underground water circulation on a large scale is an additional factor. There is absolutely no other place, within the region, where the Hudson River can be crossed from grade to grade in good ground of a single type with so great probability of avoiding all large lines of displacement."

And on page 106:

"The rock of Storm King Mountain and of Breakneck Ridge at the Hudson River crossing is a very hard granite with a gneissoid structure of variable prominence. The color varies from grayish to light reddish and the structure is always coarse passing into pegmatite facies that occur as stringers or irregular veinlets. The grayish facies is of slightly finer grain and more gneissoid. Those portions that have been sheared are still darker. There are many joints at the surface running at various angles and an occasional slickensided surface. The mass is cut by several dikes of more basic rock (diorite) of widths varying from a few inches to eight feet. These dikes are somewhat more closely jointed than the granite and consequently a little more readily attacked by the weather. But where protected they are equally substantial for underground work.

"The chief variation from this condition is where crushing or shearing has induced metamorphic changes. Wherever bed rock has been reached at this point and to such depths as workings have penetrated the rock is of this type."

With the type of structure and the location of the crossing decided on, it remained to fix the depth of the tunnel below the

river bed and to work out the designs of the tunnel and its appurtenances. The explorations to determine the depth were made by means of (1) wash borings, (2) vertical and inclined core borings on the shores and vertical core borings in the channel of the river, and (3) test shafts on the shores of the river from chambers in the sides of which inclined diamond drill borings were drilled under the bed of the river.

Early in the progress of the explorations, before the location was determined, agreements were made for putting down wash borings and core borings in the channel and along the shores. The wash borings were practically finished and the core borings were begun before a decision as to the location of the crossing was made.

Under agreement with Mr. F. W. Miller, of New York, wash borings were made on fourteen cross-sections of the river for the purpose of getting preliminary information as to the depth of the material overlying the rock. The outfit required for them was a small scow carrying a derrick and hand winch and a hand pump, together with the necessary wash rods and casings. They could be made quickly but only to limited depths, 100 to 200 ft., where they were stopped by bowlders or hard material. Sometimes two or three such holes could be put down in a day. Usually the casing was only washed down 30 ft. or so in the mud of the river bottom, far enough to guide the 1 in. wash rod, the latter going down the rest of the way without any casing. Under such conditions it was not practicable to use powder when an obstacle, such as a bowlder, was met, as the casing did not extend far enough down to maintain the hole when the powder was exploded. Only negative results were obtained, showing that ledge rock did not exist above the bottoms of the holes. It was not advisable to use any more careful or painstaking methods with these wash borings, as no positive information of the position of the rock could have been obtained by means of them alone. They cannot be relied upon for this purpose. A set of holes put down on the present Storm King line reached consistent depths of about 160 ft. It would have been unfortunate had these results been accepted as showing the position of the rock. The core borings made afterwards proved it to be at least 768 ft. deep.

In addition to a number of diamond drill borings, inclined and vertical, made on the shores of the river at Pegg's Point, New Hamburg, and Storm King to ascertain the character and formation of the rock, vertical core borings were made in the channel on three cross-sections, viz., Pegg's Point, Little Stony Point, and Storm King. All of this work was done by contractors under agreements with the board.

At Pegg's Point three holes reached and penetrated rock at depths of 92 ft., 241 ft., and 165 ft. respectively. Two of them were in Hudson River shale, a sedimentary rock composed of alternate layers of slate and sandstone, and one in the formation known as Wappinger's limestone. The distance between the two holes of 92 ft. and 241 ft. depths was 1 040 ft. In this gap was the fault line which follows the river at this point, where the preglacial gorge was probably much deeper then the depths reached by the drills.

At Little Stony Point three core borings were started in the season of 1906, but were not successful in reaching rock. One of them was lost by action of the elements, one by accident, and one was abandoned when it was found advisable to concentrate work on the Storm King line.

Naturally most of the river core borings have been made on or in the vicinity of the line at Storm King on which the tunnel is now being driven. Here 12 holes were started; 3 of them reached and penetrated ledge rock, 2 were lost through action of the elements, 2 were destroyed by tows navigating the river, and 5 were abandoned for one reason or another before they had reached ledge. These borings developed in a fairly satisfactory way the rock profile for a distance of 800 ft. from the east shore. Beyond this point nearly to the outcrops on the west shore the rock profile is not positively known. The river holes were unsuccessful in proving it, and gave only negative information of its position; that is, that it was below the depths reached by the borings. One of these holes located in the middle of the channel reached a depth of 768 ft. last December, when, after two seasons' work, operations were discontinued on account of the approach of winter. At this depth the casing was in a nest of bowlders which possibly immediately overlie the ledge.

The difficulties of making such borings in the channel of a navigable river were very great. Among other factors affecting the work should be noted the depth of the water, which, as before stated, reached a maximum of 85 ft., the necessity of doing most of the work from floating platforms, the varying currents induced by the tides, and the danger from storms and the collision of river craft. Considering the character of the work and the conditions under which it was necessarily done, it is perhaps not remarkable that more successful results were not obtained. Generally speaking, the material lying between the water and ledge is silt and clay, then a mixture of sand and clay with gravel increasing in coarseness with the depth, and bowlders. (Plate I, Fig. 2.) Little trouble was encountered in putting down the holes until a depth of between 300 ft. and 400 ft. was reached, when the bowlders interfered and caused delay. It was necessary to break them up with chopping bits or dynamite before the casing could be forced below them. At times the diamond bit was used to bore a hole through a large bowlder which could not be removed by the above means. Then it was broken by powder put into the diamond drill hole and the shattered pieces forced out of the way or removed. The removal of such a bowlder was sometimes the work of several weeks. When ledge was finally reached and the casing seated on it, most of the troubles were considered to be over, as the drilling into it with a diamond bit was a comparatively simple matter. An excellent description of this boring work is found in the paper of Messrs. Dodge and Hoke, before mentioned. The following extracts are quoted from it.

"All of the core-boring work on the river at the Storm King line has been under Contract No. 1, with the American Diamond Rock Drill Company, but has been done by their assignees, the Phœnix Construction Company.

"The equipment which experience has shown to be best and which is now in use is a piledriving scow 35 ft. by 100 ft. with ways 60 ft. high; a hoisting engine of 40 h.p. with two 7-in. by 10-in. cylinders and two 12-in. drums; two 12-in. by 7-in. by 12-in. pumps with capacity for 100 gal. per minute each at 120 lb. pressure, and a 60-h.p. boiler; casing and wash pipe of 18-in. and 14-in. steel-welded pipe, and 10-in., 8-in., 6-in., 4-in., 2½-in., and 2-in. extra heavy wrought-iron drive pipe with screw joints and

FIG. 1.

HUDSON RIVER CROSSING, CATSKILL AQUEDUCT, LOOKING WEST TOWARDS STORM KING MOUNTAIN. CORE BORING RIGS IN CHANNEL.

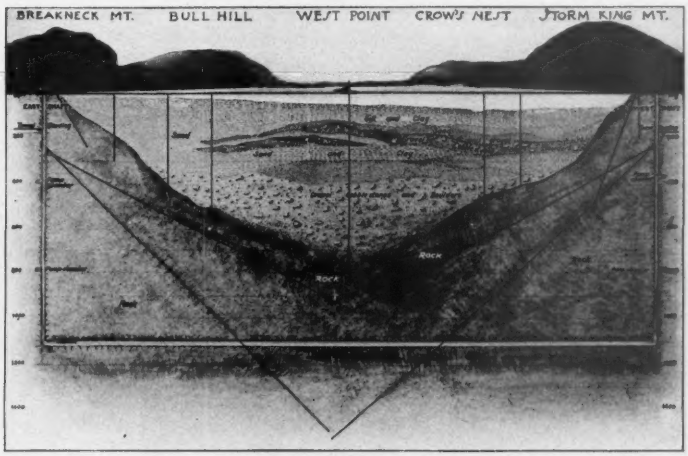


FIG. 2.

PANORAMIC VIEW AND CROSS SECTION ON LINE OF HUDSON RIVER CROSSING OF THE CATSKILL AQUEDUCT.

extra long sleeve couplings; a drilling machine; $1\frac{7}{8}$-in. rods, and enough diamonds for two bits. When the casing is surely seated in ledge and drilling under way, the large scow and other equipment for wash boring can be dispensed with, the drilling machine being carried on a platform clamped to the casing, and pump and boiler kept on a scow about 20 ft. by 30 ft.

"The scow is kept in position by at least six anchors at bow, stern, and four corners; these must be from two to three tons each and have leads of 400 to 500 ft. of $\frac{7}{8}$-in. wire cable. The severe gales and rough water encountered at times make it hard to keep the scow exactly in position, while any movement, if it is toward the hole, is likely to bend the standing casing and destroy the boring.

"The general method of boring is to sink first a line of large casing as far as possible without too severe driving, then to put down the next smaller size inside of it, 'telescoping' as it is called, and continue downward again, the telescoping of casing being repeated when necessary until bedrock is reached. A line of casing, of course, encounters skin friction against the drift material only below the bottom of the next larger casing, and in general an advance of 100 ft. or more should be made with each size, though the first two sizes should make considerably more than that in the fine material which lies on top. The importance of not having too much frictional resistance on a line of casing comes from the necessity not only of moving the line down but of being able to draw it back, so that its end will be out of harm's way when blasting is done, hence care is taken against forcing when much resistance is felt. In the early work before the great depth of the gorge was known, and when the contractor knew less of how to do this kind of boring, the mistake was made of starting with too small casing and so coming down to the smallest size practicable while still a long way from rock; this made the last of the work on these holes excessively difficult, and one of them had to be abandoned in an unfinished condition for this reason. The latest and deepest holes have been started with 18-in. casing; six reductions are then possible.

"The casing is lowered and raised by a wire cable fall passing over the sheave at the top of the pile falls to the drum of the hoister. As the casing goes down, it is added to in 20-ft. lengths, the additional piece being supported by the fall while the men screw it into the coupling at the top of the line. Great care is taken with the joint, the coupling is extra long, and an effort is made to have the pipe ends meet, so that in driving the blows of the hammer will not be carried by the threads entirely.

"The first material encountered is mud and silt, and the large casing, being very heavy, goes into it for the first 50 ft. very

easily. When light driving ceases to have an effect, a 4-in. pipe is put down inside and connected with the pump by hose and a powerful stream of water forced through it, to stir up the material just below the bottom of the casing, the water returning inside the casing and bringing up the lighter material with it. The casing is at the same time pounded lightly by the piledriver hammer, which has a hole in its center through which the wash pipe passes."

From the information obtained from these borings, the inclined holes to be described later, and a study of the physiography of the vicinity, Professor Kemp and Dr. Berkey concluded that the cross section of the bedrock gorge resembled a broad U, while Professor Crosby advanced the theory that it took the form of a wide-flaring V. Its greatest depth, of course, was between the bottom of the deepest river hole (768 ft.) and the depth at which the upper pair of inclined holes crossed each other (about 955 ft.).

When the explorations for the crossing were begun in 1905 it was realized that before actual tunneling was started under the river it would be advisable to explore the underlying rock from shore to shore with diamond drills to ascertain its character, and to show whether there existed any faults or zones of decayed or broken rock or water-bearing seams that would make the driving of a tunnel impracticable. It was realized that vertical borings in the channel, while furnishing a fairly good cross section of the preglacial gorge, would not give this essential information. In the first core boring contract, awarded February 7, 1906, therefore, a provision was made for six inclined borings to start on the shores of the river and extend under the channel to the middle. It was believed that a careful watch of these holes while they were being drilled and a study of the cores recovered would give a very good idea of the rock to be encountered in tunneling, and that some of the uncertainties of the latter would thereby be eliminated. After the first vertical borings had indicated a greater depth of bedrock gorge than was anticipated, it was found to be impracticable to start the inclined borings from the shores. The great inclinations at which they would have had to be drilled in order to keep them in the rock would have forced them too far below the river bed to be of any use for the purpose intended. It was, therefore, decided to drill them from chambers to be excavated in the sides

of test shafts at an elevation low enough to permit a flatter hole. When the sinking of the test shafts, hereinafter described, was begun in the early part of 1907 the intention was to excavate the drill chambers at about elevation — 550. The abandonment of the work by the contractor in the latter part of the same year, when only half of this depth had been reached, resulted in so much delay that when operations were resumed by the city with its own forces, in 1909, it was decided to excavate the drill chambers at the bottoms of the shafts, as they then were, before sinking deeper, in order that the drilling could be started and the needed results obtained at as early a date as practicable. This meant that the first drill holes were started at elevation — 281 and — 251.2 in the east and west shafts respectively. Two holes were drilled from each chamber, the first or lower pair being started at angles of 43° with the horizontal in the east chamber and 38° in the west chamber, and passing each other under the middle of the river approximately 1 500 ft. below tide. The second pair of holes were later started at elevations — 279.7 and — 245.8, and at inclinations below horizontal of 22° 53′ and 23° 40′ in the east and west chambers respectively. These holes crossed each other under the river about 955 ft. below tide.

When it was determined at what points the borings should be made, a form of agreement was prepared for a pair of holes to be drilled until they crossed under the bed of the river. Bids were invited from a number of concerns experienced in such work, payment to be made under two items: No. 1 to include the first 900 ft. of any hole, or for drilling the remainder beyond 900 ft. of any hole not included in Item 2; No. 2 included the remainder beyond 900 ft. of any hole which either terminated within an ordered zone or passed in solid rock above the ordered zone a hole from the opposite side of the river. The zone as indicated on the contract drawing was defined by curved lines originating at the beginning of the hole in each chamber. The upper curves intersected about elevation — 1130, and the lower ones about elevation — 1440 under the middle of the river. The zone was fixed with reference to the bedrock profile of the gorge as far as it was then known, and was designed with the idea of having the borings cross at as high an elevation as

was considered safe. The work was awarded to the low bidder, Messrs. Sprague & Henwood, of Scranton, Pa., who bid $6.50 and $10 per foot respectively for Items 1 and 2, and who promptly undertook the work. The hole in the east chamber was begun on June 1, 1909, and in the west chamber on July 29, 1909. The east hole was started at an angle of 43° and the west one at 38° with the horizontal, as before stated. These angles were selected by the contractor with the idea that the drill holes would have a tendency to turn up and thus carry them at the finish into the desired zone. Precautions were first taken to guard against this tendency to turn up too rapidly, as described by Messrs. Dodge and Hoke in the following extract from their paper regarding the first hole drilled.

"The east shaft chamber was ready in May, 1909, and hole No. 1/A-74 was started June 1. The machine, Sullivan diamond B drill, rated for 3 000 ft. of hole, was set for an angle of 43° below the horizontal, that being practically the slope of the tangent to the zone. The agreement called for a hole starting not less than $2\frac{1}{16}$ in. in diameter. Sprague & Henwood decided that the safest way to get the holes to such depths was by two successive reductions in size. The holes were started with $2\frac{1}{2}$-in. bits, reduced to 2-in. and later $1\frac{3}{8}$-in. As a precaution against a heavy flow of water, the drilling was carried on through a 3-in. gate valve attached to a 3-in. pipe grouted in the rock. To seat the pipe, the first 7 ft. of the hole was bored with a 4-in. bit.

"The drillers desired to drive the first several hundred feet as nearly straight as possible on the line set, so that great care was taken with the drilling apparatus to produce that result. The $2\frac{1}{2}$-in. bit was set as usual with eight diamonds, four to cut hole, four to cut core, and all to cut ahead, but was set to as small a clearance as possible. The diamonds projected only $\frac{1}{64}$ in. outside. The bit, shell, core barrel, and 60 ft. of rods immediately following were all the same size, actually $2\frac{1}{16}$ in. in diameter. These rods were termed guide rods. Behind the guide rods, 2-in. rods were coupled on as needed. Despite all care, a survey made when the hole was at a depth of 177 ft. showed that the boring was turning downward. The guide rods were taken off so that the sagging of the smaller rods behind the core barrel would force the bit upward. Another test made at a depth of 280 ft. gave proof that the rods were holding to a straight line and with perhaps a slight upward tendency. The hole continued at approximately this inclination, which was a trifle less than the initial slope, to a depth of 641 ft.

"Here the reduction was made to a 2-in. bit. Here, also,

whether by means of forcing the rods, as claimed, or by chance, began the first upward turn of the hole. This upward movement seemed to be increased by the use of a tapered core barrel along with a forcing of the rods, until at a depth of 1 398 ft. the survey showed the inclination at that point to be about 37° 20′. Then began another downward curve to the end.

"A small flow of water was encountered in hole 1/A-74 at a very small depth. This gradually increased as drilling progressed until at the time of the first reduction in size the flow from the open hole was 50 gal. per minute. At a depth of 734 ft. the flow had reached 90 gal. per minute and was hindering the work.

"A careless drill runner nearly ruined the hole at this point as a direct result of the back pressure exerted by the water. He did not keep his pump going hard enough to force water through the rods, and the bit was burned fast in the rock. The rods were detached from the bit, the 2½-in. hole was extended to 734.3 ft. by reaming, and the 2-in. bit, or what was left of it, was recovered as core with the steel and diamonds fused into the rock.

"In order to shut off the water, 2½-in. flush-joint casing with several diamond chips set into its lower end was placed in the hole. It was turned by the machine like rods until the bottom was burned fast to the rock as the bit had been. The water flow was reduced to 5 gal. per minute, but did not long remain so small. By the time 1 085 ft. had been drilled the open hole was sending a solid stream of water, 180 gal. per minute, 10 ft. from its mouth into the chamber. With this flow the last hundred feet of rods need not be pulled from the hole when core was being recovered; they slid out. No other advantage could be credited to the water which made drilling unpleasant work until the hole was again cased at a depth of 1 234 ft. with 2-in. flush-joint casing and again reduced in size. The water flow in this hole was one of the deciding elements for reduction in size. The quantity was lessened to 10 gal. at this final casing and did not increase beyond 70 gal. per minute, which was judged to be a limit of flow under the existing head from the now long hole.

"At a depth of 1 834 ft. the bit was again burned fast. Over two months' work failed to remove it. Diamonds, collectively valued at over $1 500, and about 600 ft. of small rods were lost. Hole No. 1/A–74 had not entered the ordered zone and did not quite reach the center of the river."

The hole from the west chamber was drilled by the same general methods. Little trouble was caused by water, the maximum flow recorded being only 5 gal. per minute. The general tendency of the hole was downward, the inclination below horizontal at the finish

being 44° 47′, or 6° 47′ steeper than at the start. On account of the abandonment of the east hole before it had reached the middle of the river, due to the burning fast of the bit, it was necessary to carry the west hole past the center point in order to pass it horizontally beyond the end of the east hole. It was driven, therefore, to a total depth of 2 051.6 ft., which is believed to be an unprecedented depth for such a boring in this section of the country.

The first pair of holes having proved beyond question the existence of sound rock under the entire width of the river channel, it was next decided to drill two more similar borings from the same chambers, but at flatter inclinations with a view to having them cross under the middle of the river between elevations −850 and −1 050. Should they succeed in passing in sound rock through this higher zone the elevation of the under river tunnel could be fixed with reference to them. Accordingly, another agreement, No. 77, was prepared and the work was again awarded to Messrs. Sprague & Henwood, the low bidders. The holes were drilled at inclinations of 22° 53′ and 23° 40′ in the east and west chambers respectively, as before stated. The east hole was drilled to a depth of 1 651.4 ft. between April 5 and August 4, 1910, and the west hole to a depth of 1 652.1 ft. between April 20 and August 25, 1910. Although they were aimed so high as to have but slight clearance in places below the rock surface indicated by the core borings, they remained in excellent rock throughout and crossed each other about at elevation −955. It is an interesting fact that the east hole, though much above the former hole drilled from the same chamber, and consequently nearer the river bed, developed a much smaller flow of water.

Much credit is due Messrs. Sprague & Henwood for the successful completion of these borings. The difficulties and discouragements met and overcome during the progress of the drilling were far greater than usually attend a work of this character. It is easy to imagine the failure of the task if placed in the hands of men of less experience and courage.

No attempt was made to ascertain the change of strike or horizontal direction of the borings, as this was not regarded as necessary. Surveys were made from time to time, however, of the inclination or dip of the holes. A knowledge of the methods em-

ployed in these surveys may be of interest, and I cannot do better than quote again from the paper of Messrs. Dodge and Hoke:

"Two methods, known as the hydrofluoric acid test and the pressure gage test, were employed.

"The hydrofluoric acid test for inclination is based on the power of hydrofluoric acid to etch glass and the principle whereby the surface of a liquid at rest under the action of gravity assumes a horizontal position. At various known depths along the boring to be surveyed, readings for the inclination are obtained from a horizontal etched line on a glass tube whose axis is parallel with the direction of the hole. These inclinations constitute a series of tangents to a compound curve which is the line of the hole itself. Of course, this method gives a determination only, as it were, in dip and not at all in strike.

"An ordinary homeopathic pill vial, $\frac{7}{8}$ in. outside diameter, $\frac{3}{4}\frac{3}{6}$ in. inside diameter, and $4\frac{5}{8}$ in. long, containing a solution of nine parts by volume of water and one part by volume of hydrofluoric acid, is placed in a water-tight steel shell, about a foot long, which is the same diameter as the rods in use and is bored to exactly hold the bottle. The shell or tester is coupled to the rods and lowered into the hole. During the time required for lowering the rods no definite line is etched because the rods in turning apply the acid to all sides of the tube and because the solution is made weak in order to reduce the action as much as possible. When the required depth is reached the rods are clamped and allowed to rest long enough for the acid to do its work. At great depths the period at rest required to give a well-defined line is about an hour. The rod is rapidly withdrawn and the acid emptied from the recovered tube.

"For the survey of these holes, the angles were read by placing the record tube in a machine constructed for the purpose. The tube was clamped to a revolving pivot in such manner that the etched line and the side of the bottle could in turn be sighted in parallel with a straight edge which is the diameter of a graduated semicircle protractor. A reading was taken of the position of a needle which was rigidly connected with the pivot and played over the graduated arc. The difference in readings gave the observed angle. Owing to the effect of capillary attraction on the acid solution, the observed angle was not the true angle. A minus correction varying from 4° for a reading of 26° 24′ to 8° for a reading of 52° 05′ had to be applied to obtain the true slope. A correction diagram was prepared by taking readings on tubes exposed to known slopes. The final accepted angle was an average of twenty-four readings made by two independent observers. Tests were made not more than a hundred feet apart.

"The hydrofluoric acid test was the most used method of making surveys, but it had one objection, — one erroneous reading changed the position of all the hole below it. It is apparent therefore, why the precautions above described were taken to eliminate the danger of such an error.

"The other method tried was that of a recording pressure gage, designed and made by Dr. Herbert T. Kalmus and Mr. Gilbert N. Lewis, of the Massachusetts Institute of Technology. The gage was made so that it could be inserted in a hole and lowered to the desired point by means of a pliable wire cable. From the flow of water, the holes were always full, and the object was to measure the static head at any point, preferably near the bottom, as the location of the ends of the holes was most important. Accordingly, the gage was designed for only heavy pressures.

"The gage consisted of a flat steel tube with a certain resisting power which was placed in the lower end of the inch tube encasing the whole gage, so that it could be exposed to the external pressure of the water. To the top of the flat tube and in a water-tight compartment of the casing tube was connected a glass capillary tube which opened into a small cup. The flat steel tube and the glass tube were filled with mercury when the instrument was ready for a test.

"Now when the gage was subjected to pressure the steel tube was compressed and forced mercury into the cup from which it could not return when the pressure was removed. Then by simply reading the height of mercury in the tube, the pressure to which the gage had been subjected was known. The instrument, of course, had been calibrated by applying known pressures and marking the heights of mercury.

"The principle of obtaining the vertical distance of a point at known depth below the top of the hole was excellent, but the machine did not always work well under the conditions which obtained. The gage recorded only the highest pressure, and it was practically impossible to lower the gage so that higher pressures than that of the static head would not be recorded. The movement of the gage through the water affected the pressure. All sorts of schemes were tried to offset the disadvantage. Even when the pressure was allowed to reach the flat steel tube only through a 3-ft. capillary tube, impact pressures were sometimes recorded, in which cases the machine would not check either itself or the survey by the hydrofluoric acid test, and no credence could be placed on the results, although the principle of the method was a better one."

It was decided to sink the two test shafts before referred to as a part of the scheme of exploration. They were so designed as to

form part of the permanent construction should the explorations prove the feasibility of the location. The upper 225 ft. or so of the west shaft above the proposed connection with the land tunnel were made rectangular, to be closed later, that portion being of use only as a construction shaft. Below the land tunnel the west shaft was made circular for use as a waterway shaft, of a size to finish inside of concrete lining, with a diameter of 14 ft. The east shaft was made circular from the top down with a view to lining it throughout and maintaining it as a permanent shaft, that portion above the proposed land connection being intended as a pumping shaft to be used for unwatering the siphon when necessary in the future. Both shafts were so located as not to interfere with the present or proposed future positions of the Hudson River and West Shore railroad tracks. The west shaft is about 120 ft. back from the river at the foot of the north slope of Storm King Mountain, where the elevation of the ground surface was about +40. The east shaft is 100 ft. from the river shore on the projection of Breakneck Point, where the elevation of the ground was +31.5. Through Breakneck Point the Hudson River Railroad passes in a rock tunnel, and the shaft is between this tunnel and the public road which skirts the river shore. The location of the east shaft was on a steep rock slope, and before beginning the sinking the site was excavated in open cut to the approximate level of the road, or about elevation +12. The shafts are 3 022.3 ft. apart on centers, and the tunnel line between them is straight.

Ground was broken for the east shaft on February 14, 1907, and for the west shaft on March 7, 1907. Under the agreement with the contractor, he was to go, if required, to elevation −650 with both shafts. At the time the agreement was signed it was not known even approximately what the depth of the rock gorge was, the deepest boring in the river at that time having reached a depth of only 482 ft. Elevation −650 was fixed as the maximum depth we were then justified in sinking the shafts with the information at hand.

On December 7, 1907, when the east shaft was down to elevation −249 and the west shaft to elevation −226, the contractor stopped work. The complications which followed delayed the resumption of the work of sinking more than a year, when it was started again

by the board with its own forces under the immediate supervision of the division engineer, Mr. William E. Swift. By this time the river borings had proceeded far enough to indicate a much greater depth of rock gorge than was supposed when the shafts were started, and it was decided to make preparations to sink them deeper than was provided in the contract. A depth of 1 200 ft. below tide was tentatively fixed until more positive information from the boring operations should be available. It was also decided, as before stated, to begin the inclined borings under the river as soon as chambers could be prepared for them at the bottoms of the shafts.

Before resuming actual excavation, the derricks used by the contractor were taken down and headframes constructed over the shafts. These frames were designed so that they could be used not only for completing the shafts, but for driving and lining the tunnels under the river. New hoisting engines were installed of a much heavier type than those employed before. A new air-compressing plant was assembled for the west side, and the compressors, which the contractors had used for both shafts, were grouped for use at the east shaft. Other additions and improvements were made in the plant with a view to meeting the requirements of greater depth and to insure safety and consistent progress.

During the interval when the work was suspended the shafts had filled with water and it was necessary to empty them out before resuming excavation. This was accomplished with comparatively little trouble by bailing and pumping. On March 3, 1909, excavation was again started in the east shaft, and on June 2, 1909, in the west shaft. The diamond drill chambers were first excavated, as before stated. These were of considerable size, large enough not only to permit the drills to be conveniently operated, but the drill rods to be removed and replaced in 30-ft. lengths. The chambers were excavated on inclines of about 45°, which added to the difficulty of the work, the incline being necessary to allow the rods to be pulled in the direction of the borings. On the completion of the chambers, shaft sinking was resumed and continued until the bottom was reached. The diamond drilling was not started until the shafts were approximately 50 ft. below the chamber, so as to insure the machines against injury

from blasting and also reduce the chance of the latter jarring the rock about the drill holes to the extent of blocking them. Large pump chambers of a size sufficient for three Jeanesville pumps (2 cylinder, 16 in. by 7 in. by 18 in.) were made in the sides as the shafts were sunk. These chambers are approximately at elevations −400 and −800, the idea being to pump in 400-ft. lifts, the bottoms of the shafts being assumed at elevation −1200, as before mentioned.

During the progress of the shaft sinking, the two pairs of inclined borings were completed and furnished data from which the elevation of the river tunnel could be fixed. The rule followed for other siphons of the aqueduct was to place the tunnel under a cover of sound rock at least 150 ft. thick. Following this rule, which was suggested by Senior Designing Engineer Wiggin, the elevation of the river tunnel was established approximately that distance below the elevation at which the upper pair of inclined borings crossed (about −955). It is not known what thickness of bedrock exists above this elevation and it was thought best to be conservative. The intrados of the concrete tunnel arch at the foot of the east shaft is to be at elevation −1100, and the corresponding point on the west side −1097. The drop of three feet is provided so that the water may drain to the sump at the east shaft when the siphon is unwatered in the future.

The shafts were sunk deep enough for, and the first rounds of holes were drilled for, the river headings on December 23, 1910, and February 13, 1911, in the east and west shafts respectively. After the tunnel from each shaft was driven 100 ft. or so, the pump chamber at the bottom and the deep permanent sump under the east shaft were excavated. The guides were then put in place for the cages and the latter were installed. The timbering of the shaft permitted room for only one cage in each shaft. Everything was then in readiness to proceed with the driving of the tunnel.

The west shaft is remarkably dry considering its depth below the drainage level of the country and its proximity to the river. About 30 gall. of water is pumped from it per minute. The east shaft is much wetter, however, the inflow amounting to 140 gal. per minute, most of which appears in the vicinity of the pump chamber at elevation −400.

When the shafts had reached their final depths and the headings were started at the elevations noted, it was considered that the exploration work was finished and it was deemed advisable to have the remaining work done by contract. Accordingly Contract 90, "For the Completion of the Hudson Siphon," was prepared and advertised, and on June 20, 1911, was awarded to the T. A. Gillespie Company, who began work on June 22, and who on September 6 had advanced the west heading a total distance of 853 ft. from the shaft. No advance has been made by them in the east heading for reasons to be stated. Taking both tunnels together, over one third of the total length of heading is now driven.

Contract 90 includes particularly the following: (1) The completion of the tunnel excavation under the river; (2) the lining of the tunnel with concrete to a finished diameter of 14 ft.; (3) the lining of the west shaft to the same diameter up to the land tunnel connection and the sealing and partial refilling of the shaft above it; (4) the lining of the east shaft to a finished diameter of 14 ft., with concrete guides for a cage and a pump float, and the furnishing and placing of the metal seal above the land connection; (5) a hydrostatic test of the shafts and tunnel if required; and (6) the construction of a drainage chamber over the east or pump shaft.

While this contract was being prepared and until the contractor took hold on the date named, the board's forces continued work and drove the headings from the east and west shafts a distance of 268 ft. and 218 ft. respectively. On April 21, 1911, when the east heading was at the distance named, a flow of water amounting to about 250 gal. per minute was encountered in firing the cut in the heading. At this time the large station pumps had not been installed in the bottom for fear the blasting would injure them, and it was necessary to fight the flow with the smaller pumps available for the purpose. Before the water was finally under control it had filled the tunnel to the roof, submerging some of the pumps. On May 5, however, the tunnel was emptied and three large station pumps have since been put in position to handle the water. A 4-in. pipe was inserted into the hole in the cut from which the flow came and was carefully braced and concreted in. The pipe was then continued to the shaft and up the latter 300 ft. to the pump chamber at elevation −800. After the

concrete in the plug had set, the valve in the T of the pipe near the heading was closed and the water rose by its own head to the chamber. This was, of course, a temporary expedient to get the water out of the way while arrangements were being made in the tunnel to handle it easily. The pipe will have to be taken away before the heading can be advanced. Under the requirements of Contract 90 the contractor is also preparing to install two electrically driven centrifugal pumping units, each of a capacity to discharge 500 gal. per minute from the bottom to the top of the shaft. With this outfit, should the equipment, either of centrifugal or reciprocating pumps, go out of commission temporarily, the other equipment can handle the water up to its capacity.

As an additional precaution the contractor has built, by direction, a heavy concrete bulkhead in the tunnel between the pumping station and the heading. This will be equipped with a cast-steel door swinging on hinges with the flow, which can be readily closed in the event of an accident to the pumps or of a sudden inflow of water that would overtax their capacity, thus preventing the drowning of the pumps while additional pumping units are being installed. The bulkhead and door are designed to withstand a hydrostatic pressure equal to the full depth below the river surface. The bulkhead is 14 ft. thick in the center and about 18 ft. at its contact with the rock of the tunnel.

Advantage has been taken of the delay incident to the installation of the pumping plant and the building of the bulkhead to put in an additional diamond drill hole in the face of the heading parallel with the axis of the tunnel. Although this hole was started only a few feet over the point in the face where the water-bearing seam was encountered, it had advanced on September 6 a distance of 468 ft. and flows only 32 gal. per minute, about half of which was encountered within 10 ft. of the face of the heading. This boring is made under a provision of Contract 90 and the work is being done for the contractor by Messrs. Sprague & Henwood, of Scranton, Pa., who drove so successfully the inclined holes from the shafts.

The flow of the water into the east heading was the subject of a number of sensational newspaper articles published soon after it was encountered. While it was no doubt the cause of some delay

to the work, it did not give rise to such alarm on the part of those on the work as casual readers of the newspapers would suppose. The amount of water, which now totals, with the flow in the shaft itself, to about 350 gal. per minute, is small when compared with that encountered in one of the headings of the pressure tunnel under the Rondout Valley, which amounted to 2 000 gal. per minute. This flow, diminishing gradually to 1 200 gal. per minute, has been pumped for many months past through a 500-ft. shaft to the surface. In spite of the interference with the progress which it caused, the tunnel has been successfully driven through the porous rock and is now in process of being lined with concrete.

It is interesting to note that analyses of samples of the water coming into the Hudson River tunnel through the seam mentioned show it to contain much more chlorine than samples of the river water taken at the same time, even at flood tide when the chlorine content of the river water is a maximum. For instance, samples taken from the river at low tide and from the tunnel on June 12, 1911, showed 14.5 parts and 4 150 parts of chlorine respectively per million. The tunnel water has been referred to by the geologists as "fossil" water that has been stored for ages in the seams far below the drainage level and below the zone of circulation.

The heading from the west shaft has been practically dry the entire distance of over 800 ft. A similar equipment of pumps, however, is to be installed there as in the east tunnel, and a concrete bulkhead built. The contract provides that "if ordered in any stretch of tunnel a test drill hole to be paid for" by the city "shall be carried about 10 ft. in advance of holes used for blasting." These holes, called "pilot holes," are intended to give warning, before blasting is done, of any water-bearing seam which may be in advance of the heading, and the precaution of drilling them is being followed regularly, though not always to the full depth of 10 ft. which may be required.

An interesting feature of the shaft sinking and tunnel driving is thus described by Messrs. Dodge and Hoke:

"A phenomenon which is peculiar and disconcerting to the workmen in the shafts is that of popping rock. Without warning there will be a loud report like a pistol shot, and a piece of rock from the wall will fly into or across the shaft. Usually the frag-

ment is small and does no damage, but at times has caused injuries of minor nature. This popping may occur from rock surfaces which have been uncovered several days. It has not been very frequent and was first noticed in the west shaft at elevation —450. Prof. W. O. Crosby has explained the phenomenon as an explosion resulting from the local relief from mechanical pressure to which the rock is subjected by the wedge-like structure of the granite underlying the river. He says:

"'The relief will normally find expression either in scaling or in the development of cracks or rifts, which, tending to be parallel with the east and west sides of the shafts, will rather seldom be subject to direct observation. Every such snapping or sudden giving way or rifting of the granite gives rise to a miniature earthquake.

"'I may add that this is a fairly common happening in mines and quarries. Often in quarries the compressive strain is measured by an appreciable stretching of the rock when released, so that it would be impossible to force a block into the space which it formerly occupied. This phenomenon of spontaneous snapping and rifting has recently been described as occurring in some of the deep Lake Superior copper mines.

"'That it was not observed nearer the surface in the Hudson River shafts is probably due to the relief long since afforded by the erosion of the gorge of the Hudson. It should not be regarded as jeopardizing appreciably the security of either shafts or tunnel, and it is evident that we have here a powerful agent tending to tighten and close up seams in the granite.'"

I cannot close this paper without calling attention to the very efficient service rendered by the division engineer, Mr. William E. Swift, in connection with the work described. He has been in direct charge of this particular problem from the inception of the work in 1905 until the present time. Under the chief engineer, Mr. J. Waldo Smith, it is due, in a large measure, to Mr. Swift's zeal and to his intelligent attention to the work that so many obstacles to success have been overcome and that the tunnel is so far advanced toward completion.

The designs for the pressure tunnel and its appurtenances were made by Mr. Thomas H. Wiggin, senior designing engineer, and his assistants, working under the direction of Mr. Alfred D. Flinn, engineer in charge of headquarters department, and of the chief engineer. The specifications for Contract 90 were prepared by headquarters department with the coöperation of Mr. Ralph N.

Wheeler, division engineer, Northern Aqueduct Department. The writer has had general supervision of the field work as engineer in charge of the latter department. He is indebted to Mr. Wheeler for much assistance in the preparation of this paper.

PROTECTION OF STEEL PIPES IN CATSKILL AQUEDUCT.

BY ALFRED D. FLINN, DEPARTMENT ENGINEER, BOARD OF WATER SUPPLY OF THE CITY OF NEW YORK.

[*Read September 14, 1911.*]

New York City's Catskill water system, final surveys for which were begun six years ago, is now so well known that even a brief outline is unnecessary as a foreword to this paper. In the 92 miles of 500-million-gallon aqueduct between Ashokan Reservoir and the city line there are numerous valleys to be crossed, varying in width from a few hundred feet to several miles. For fourteen of these depressions, steel-pipe siphons were determined upon as the most economical and otherwise suitable type of construction. Seven siphons are in the Northern Aqueduct department north of Croton watershed, and the remaining seven are in the Southern Aqueduct department; they are being constructed under two corresponding contracts: No. 62, with the Snare & Triest Company, and No. 68, with the T. A. Gillespie Company. West of the Hudson River there are three siphons, and east of the river, eleven.

To convey water to the full capacity of the other portions of the aqueduct, three pipes will ultimately be required, but since the city does not need the whole capacity for a number of years, only the middle pipe of each siphon is now being laid. Between Ashokan Reservoir and the Croton divide, the pipes are approximately 9 ft. in diameter; from the Croton divide to the connection for the proposed filter plant they are about 9.5 ft. in diameter; and from the latter point to Hill View Reservoir, 11 ft., for economical reasons, depending upon the available slope. Of course, the middle pipe alone will carry far more than one third the capacity of the three pipes all together,— the capacity of one pipe alone, when forced, being estimated at approximately 350 million gallons daily. At each end of each siphon is a concrete siphon chamber, forming the connection with the ad-

jacent cut-and-cover or tunnel portion of the aqueduct. In each chamber, sluice gates for controlling the flow of water into the several pipes will be installed. These chambers will have suitable superstructures; the chambers, but not their superstructures, are included in the contracts mentioned.

TABLE I.

DIMENSIONS OF CATSKILL AQUEDUCT PIPE SIPHONS.

NORTHERN AQUEDUCT DEPARTMENT.

West of Hudson River.

Name of Siphon.	Length Feet.	Thickness of Plate, Inches, and Kind of Joint.	Maximum Head, Feet.	Diameter of Pipe Shell.	Finished Diam. of Siphon.
Esopus	2,110	$\frac{7}{16}$; lap.	107	9 ft. 6 in.	9 ft. 2 in.
Tongore	643	$\frac{7}{16}$; lap.	72	9 ft. 6 in.	9 ft. 2 in.
	53	$\frac{9}{16}$; long. seams butt-jointed.			
TOTAL	696				
Washington Square,	3,281	$\frac{7}{16}$; lap.	90	9 ft. 6 in.	9 ft. 2 in.

East of Hudson River.

Foundry Brook	3,490	$\frac{7}{16}$; lap.	192		
	288	$\frac{1}{2}$; lap.		9 ft. 6 in.	9 ft. 2 in.
TOTAL	3,778				
Indian Brook	608	$\frac{7}{16}$; lap.	70	9 ft. 6 in.	9 ft. 2 in.
Sprout Brook	1,061	$\frac{7}{16}$; lap.	234	9 ft. 6 in.	9 ft. 2 in.
	119	$\frac{1}{2}$; lap.			
	1,044	$\frac{1}{2}$; long. seams butt-jointed.			
TOTAL	2,224				
Peekskill	2,162	$\frac{7}{16}$; lap.	340	9 ft. 6 in.	9 ft. 2 in.
	218	$\frac{1}{2}$; lap.			
	1,251	$\frac{1}{2}$; long. seams butt-jointed.			
	1,876	$\frac{9}{16}$; long. seams butt-jointed.			
	1,025	$\frac{11}{16}$; long. seams butt-jointed.			
	139	$\frac{3}{4}$; long. seams butt-jointed.			
TOTAL	6,671				

FOUNDRY BROOK SIPHON.

Whitewashed 9 ft. 6 in. pipes; finished earth trench with one type of concrete cradles in foreground.

TABLE 1.— *Continued.*

SOUTHERN AQUEDUCT DEPARTMENT.

Name of Siphon.	Length Feet.	Thickness of Plate, Inches, and kind of Joint.	Maximum Head, Feet.	Diameter of Pipe Shell.	Finished Diam. of Siphon.
Hunters Brook	1,493	$\frac{7}{16}$; lap.	110	9 ft. 9 in.	9 ft. 5 in.
Turkey Mountain..	1,510	$\frac{7}{16}$; lap.	92	9 ft. 9 in.	9 ft. 5 in.
Harlem Railroad...	694	$\frac{7}{16}$; lap.	60	9 ft. 9 in.	9 ft. 5 in.
Kensico	1,625	$\frac{7}{16}$; lap.	50	9 ft. 9 in.	9 ft. 5 in.
Elmsford.....	1,490	$\frac{7}{16}$; lap.	68	11 ft. 3 in.	10 ft. 11 in.
Fort Hill.....	1,267	$\frac{7}{16}$; lap.	72	11 ft. 3 in.	10 ft. 11 in.
Bryn Mawr.....	2,714	$\frac{7}{16}$; lap.	214	11 ft. 3 in.	10 ft. 11 in.
	150	$\frac{1}{2}$; lap.			
	2,465	$\frac{1}{2}$; long. seams butt-jointed.			
	255	$\frac{9}{16}$; long. seams butt-jointed.			
TOTAL.....	5,584				

Total length of all siphons, 33,031 ft.

Efficiency of single-riveted lap joints, about 50 per cent.; double-riveted lap joints, 70 per cent., and of triple-riveted butt joints, 81 per cent.

Having settled upon metal pipes, the next most important phase of the problem was to make these siphons as nearly as feasible comparable in durability to the masonry types of aqueduct. Attention was directed first to finding a pipe metal less corrodible than steel. Such evidence as was at hand and could be collected within the time at our disposal, pointed to genuine wrought iron as being possibly superior in this respect to other metals. Investigation, however, disclosed the facts that wrought iron could not be obtained in sufficiently large sheets, and its strength would be less, hence the thicknesses of the pipes would be greater, leading to greater cost. Cost would not have been a controlling factor if satisfactory assurance of accomplishing the desired result had accompanied increased expenditure. Deliveries, furthermore, would probably have been too slow for the necessary progress in construction. Consequently, it was decided to use the best available quality of steel.

Steel having been selected as the metal for the pipe plates, attention was directed to the best method of protecting it. Reports of experience from many places and special examinations

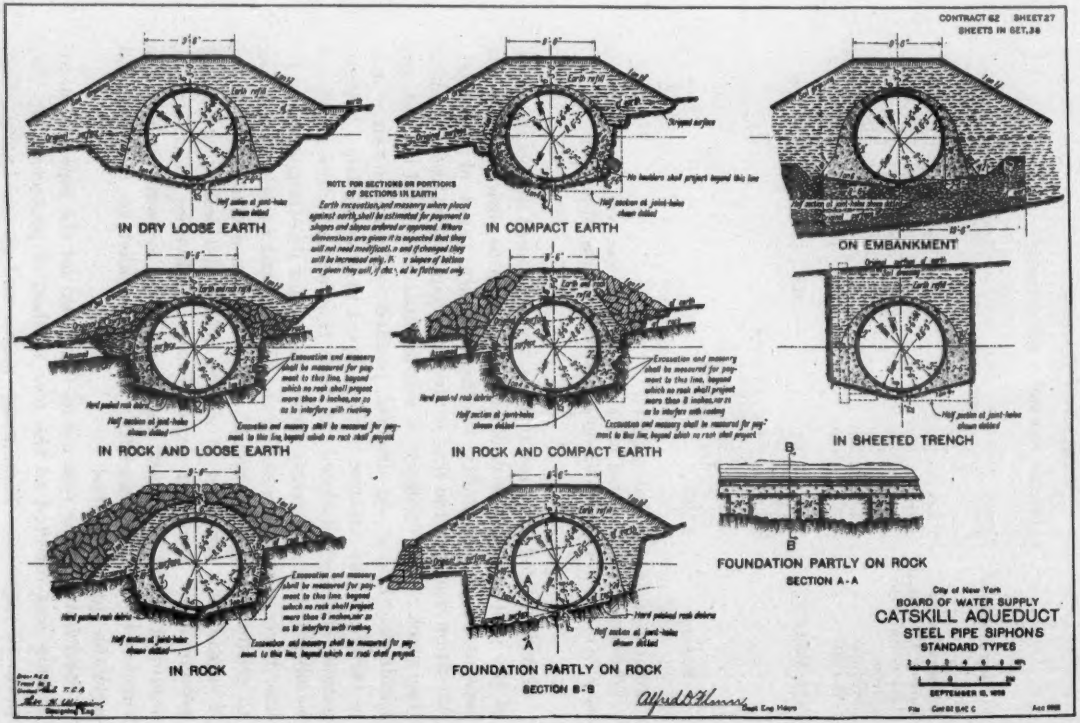


FIG. 1.

STANDARD TYPES OF TRENCH, EMBANKMENT, AND JACKET, SIMILAR FOR ALL SIZES OF PIPE.

of many steel pipe lines of varying ages gave convincing proofs that none of the pipe coatings commonly used was possessed of qualities giving it more than a few years' useful life, with our waters and soils. One or two cases of use of Portland cement mortar on a small scale in pipes, and wide experience in reinforced concrete construction, of the protective action of Portland cement on steel, pointed to a method for coating the pipes. After some study it was decided to jacket the steel siphons of the aqueduct outside with rich concrete mixed about one part of cement to three parts sand and six parts broken stone or gravel, with a minimum thickness of 6 in., and to line them with Portland cement mortar, 2 in. thick at the minimum. Standard cross sections of the pipes are shown in Fig. 1.

Methods of applying the concrete and mortar next received consideration. Improvements for attaining intimate, complete, and permanent adhesion in spite of the unavoidable changes in shape and the elastic distortions of the pipes were sought, along with the most economical and practicable methods for the various steps in covering and lining. Preparation of the steel to receive concrete and mortar was also carefully studied. Numerous experiments were conducted especially on placing the lining.

Mortar lining experiments were made at nearly full size. A steel pipe 9 ft. in diameter and 12 ft. long, of $\frac{3}{8}$ in. riveted plates, was lined by plastering with metal reinforcement of several styles, by plastering with terra cotta and cement blocks or tiles, and by pouring grout or very thin mortar into the space between a cylindrical steel form and the interior surface of the pipe. To summarize the results briefly, no combination of plasterer's skill with various kinds of Portland cement mortar, reinforced or unreinforced, gave linings that were adequate, and this method was expensive. Bedding tiles of terra cotta or mortar about $\frac{3}{4}$ to $\frac{7}{8}$ in. thick and 6 by 8, 6 by 12, and 8 by 12 in. on mortar applied directly to the pipe surface, and, after setting, building up the lining to the required thickness with successive coats of mortar troweled on was much more satisfactory, but was also expensive. The grouting method proved by far the most satisfactory and least expensive and was made the basis of the specifications. With proper regard for certain details, this last method gave promise of being feasible

in actual construction. It also had the advantage of producing a monolithic lining, which was considered desirable, especially in the avoidance of layers, or lamina, in the thickness, since it is well known to be difficult to cause one layer of Portland cement mortar or concrete to adhere absolutely and permanently to another without expensive and troublesome precautions. As the successive experimental linings were removed from the test pipe it was observed quite generally that linings applied in layers separated.

As the result of these studies and experiments, the following specifications were written:

Extracts from Contract 62.

GENERAL SECTIONS.

Order of Work.

Sect. 19. The steel pipe shall be laid, tested, and made tight against hydrostatic pressure; then surrounded by concrete while still under the normal hydrostatic pressure, after which the mortar lining shall be placed. Except at overhead stream crossings, no stretch of pipe shall be left not well protected from frost between stretches of pipe around which concrete has been placed. As soon as practicable after the concrete covering and mortar lining have been placed, the pipe shall be covered with earth; and all pipe covered with concrete, whether or not mortar lining has been placed in it, shall be protected in freezing weather by at least one foot of earth.

9½-FOOT STEEL PIPE.

(Items 19 to 24.)

Work Included.

Sect. 19.1. Under Items 19 to 24 inclusive, the contractor shall furnish and lay, test, and make tight the 9-ft. 6-in. steel pipe between the siphon chambers at each siphon. The pipes will vary in thickness according to depth below the hydraulic gradient of the aqueduct, and are grouped in the six items according to thickness, irrespective of location.

Material.

Sect. 19.2. Steel for plates and rivets shall be made by the basic open-hearth process. Steel for plates shall fulfill the requirements for " flange steel " and rivets for " extra soft steel " as given

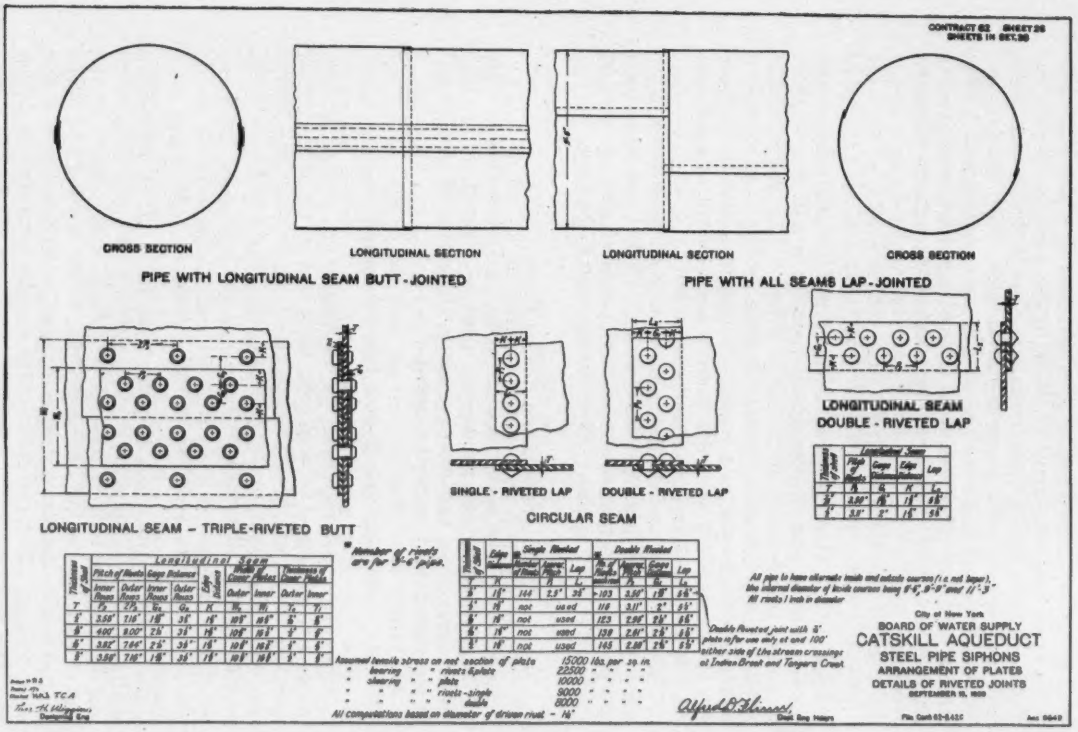

CONTRACT 62 SHEET 28
SHEETS IN SET 30
CROSS SECTION
LONGITUDINAL SECTION
LONGITUDINAL SECTION
CROSS SECTION
PIPE WITH LONGITUDINAL SEAM BUTT-JOINTED
PIPE WITH ALL SEAMS LAP-JOINTED
LONGITUDINAL SEAM
DOUBLE-RIVETED LAP
LONGITUDINAL SEAM – TRIPLE-RIVETED BUTT
SINGLE-RIVETED LAP
DOUBLE-RIVETED LAP
CIRCULAR SEAM
Longitudinal Seam
Pitch of Rivets
Gage Distance
Width of Cover Plates
Thickness of Cover Plates
Inner Rows
Outer Rows
Lap
Single Riveted
Double Riveted
Assumed tensile stress on net section of plate 15000 lbs. per sq. in.
bearing " " rivets & plate 22500 " " "
shearing " " plate 10000 " " "
" " " rivets - single 9000 " " "
" " " " double 8000 " " "
All computations based on diameter of driven rivet - 1/16"
All pipe to have alternate inside and outside courses 1/4 in. not lapped, the internal diameter of inside courses being 9'-6", 8'-9" and 11'-3"
All rivets 1 inch in diameter
City of New York
BOARD OF WATER SUPPLY
CATSKILL AQUEDUCT
STEEL PIPE SIPHONS
ARRANGEMENT OF PLATES
DETAILS OF RIVETED JOINTS
SEPTEMBER 15, 1909
Alfred D. Flinn
Chief Eng Helper

FIG. 2.

STANDARD JOINT AND RIVET DETAILS, SIMILAR FOR ALL SIZES OF PIPE.

in the Standard Specification for Open-Hearth Boiler Plate and Rivet Steel, adopted August 16, 1909, by the American Society for Testing Materials. All specimens and records shall be furnished and analyses and tests made as therein provided. The engineer shall be informed in advance of all times of sampling and testing and be permitted to witness such of these operations as he desires. Duplicate samples shall be furnished to the engineer whenever required.

Dimensions.

SECT. 19.3. The pipes shall be made with alternate inside and outside courses, and the designated diameter of 9 ft. 6 in. shall be measured as the inside of the inside course. The lengths of the courses, unless otherwise permitted, shall be 7 ft. 6 in. center to center of circular joints on regular straight pipe, and on the long side of courses cut or beveled to form angles or curves. Each course shall be formed of not more than two plates.

The plates used and the design of joints shall be as given in the table on Sheet 26 [Fig. 2] of the drawings. Slight variations from the dimensions given will be allowed provided they do not, in the opinion of the engineer, affect the strength of the joint.

Shaping and Rolling Plates.

SECT. 19.4. The plates shall be rolled to true cylinders while cold. No heating nor hammering shall be allowed for shaping or curving, nor for any other purpose. All parts shall be adjusted to a perfect fit and properly marked.

Other than Riveted Joints Permitted.

SECT. 19.5. Joints formed by welding or by special devices, giving strength equal to or greater than that of the riveted joint specified above, will be allowed on proof of efficiency and lasting qualities satisfactory to the engineer, but no reduction in thickness of plate will be considered.

Planing and Calking.

SECT. 19.6. The edges of plates that are $\frac{1}{2}$ in. or more thick shall be planed. Lap joints shall be calked all around, both inside and outside, and butt joints shall be calked outside only. At the end of each course and at the junction of the circular and longitudinal seams, the plates shall be reduced by hammering to a fine edge, through which two rivets of the circular seam shall be driven to insure tightness.

Rivet Holes.

SECT. 19.7. The work shall be carefully and accurately laid out and all rivet holes shall be spaced with precision. Holes in $\frac{1}{2}$-in. and thicker plates shall be drilled from the solid or punched to an approved size and reamed. Punched holes shall be clean cut, without torn or ragged edges, and in punching only the best and sharpest punches and dies shall be used. The engineer shall have the right to order a change of punch or die whenever the holes are not punched to his satisfaction. All burrs or splits caused by punching shall be removed by counter-sinking.

Holes Not Drifted.

SECT. 19.8. Corresponding holes shall, without enlarging, coincide to within about $\frac{1}{32}$ in., and all plates in which corresponding holes do not so coincide shall be rejected, unless the engineer shall be of the opinion that the conditions of stress are such at the point in question as to make a more extensive enlargement safe. Drift pins shall not be used in forcing holes, but any perceptible lack of coincidence in acceptable plates shall be corrected by a sharp reamer or drill.

Riveting.

SECT. 19.9. All riveting in longitudinal seams shall be done by hydraulic, compressed air or steam machinery, exerting a pressure on each rivet sufficient to produce the best results. This pressure shall be retained until the rivet head has been perfectly formed and the metal has lost its red color. Before any rivets are driven, the plates shall be brought into close contact by a suitably applied pressure, which shall be maintained until the rivets are driven. All rivets shall be driven at such heat as to give the best possible results. Any rivet that is in any way defective shall be cut out and replaced by one that is acceptable. All rivets shall be perfect in form; when driven they shall completely fill the holes and have heads of proper form and size, free from checks and cracks, and truly concentric with the shank. Rivets of extra length shall be used when riveting through more than two thicknesses, and in all places where castings or flanges of any description are to be attached to the pipe. All rivet heads inside the pipe on the butt strap of the smaller rings of pipe shall be of an approved flattened shape, substantially as shown on Sheet 6; all rivets may be so made, if desired.

Samples of Riveting.

In order to prove the sufficiency of proposed rivet driving pressures and of methods and apparatus for both shop and field

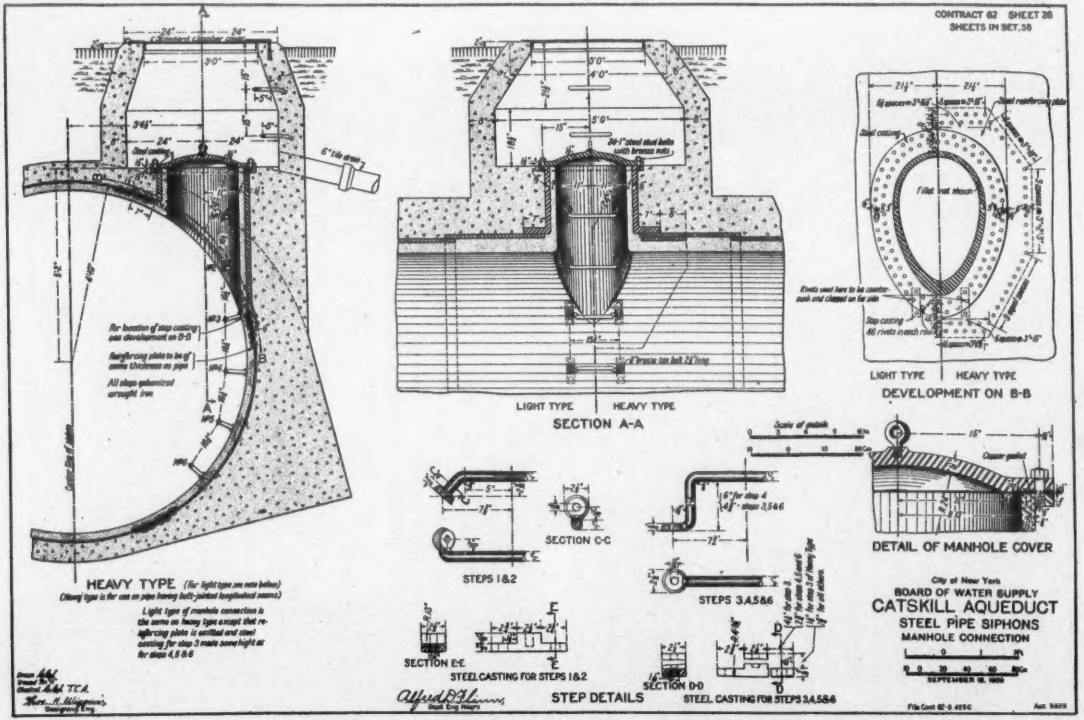


FIG. 3.

STANDARD MANHOLES FOR STEEL PIPE SIPHONS.

joints, the contractor shall supply, as directed, samples of each kind of joint and riveting both in thin and in thick plates. These samples will be from 5 in. to 10 in. wide and 12 in. to 30 in. long after fabrication. Not over fifteen samples will be required unless the results of any test indicate unsatisfactory methods, in which case such tests shall be repeated until satisfactory methods are used.

Testing Samples.

The contractor shall do such sawing as required through plates and rivets, to show the degree of closeness with which the rivets fill the holes. Labor and materials required to furnish and test these samples, as above specified, will not be estimated for payment, but compensation therefor will be considered as included in the prices stipulated for the various items of steel pipe.

Connections.

SECT. 19.10. Manhole, blow-off, and drain castings paid for under Item 25 are to be attached to the pipe as shown on Sheets 28 [Fig. 3], 30 [Fig. 4], and 33 [Fig. 5]; the pipe is to be reinforced at certain manholes and at all ends entering the castings at siphon chambers. An air-valve is to be connected to the pipe at Peekskill siphon and one at Foundry Brook siphon, the reinforcement of the plate and cutting and threading of the hole being included in these items. All cutting, punching, riveting, calking, and other work necessitated by these connections shall be included in the prices stipulated for these items and for Item 25 (steel castings).

Hand and Grout Holes.

SECT. 19.11. Holes tapped for 2-in. pipe, for introducing hot rivets, and for grouting shall be provided in the top of the pipe as nearly as practicable at the uphill end of each outside course, in order to prevent air pockets during grouting. Additional holes shall be placed as required at curves, where lining is to be built in short lengths. These openings in $\frac{7}{16}$-in. and $\frac{1}{2}$-in. plates shall be reinforced by a plate riveted on, or in some other approved manner, and shall be closed after grouting by threaded plugs, so as to be water-tight.

Curves.

SECT. 19.12. Wherever changes in line or grade of the pipe make angles necessary, they shall be formed by cutting and beveling the ends of a sufficient number of courses to produce the desired total deflection or curvature.

Stopping Leaks; Rivet Calking.

SECT. 19.13. All leaks shall be stopped by suitable calking with the proper tools. Rivet calking shall not be allowed if the rivet is loose, nor unless the leak is very slight and easily closed. Otherwise the rivet shall be cut out carefully and a new one inserted and headed up tight while hot. If the leaks are numerous and of a nature not to be well repaired, the whole section shall be rejected.

Transportation.

SECT. 19.14. During transportation and in loading and unloading the pipes, more than ordinary care shall be taken to prevent injury, and such work shall be done slowly, with the pipe at all times under perfect control, and under no conditions shall a pipe be dropped. In distributing the pipes in the field, each piece shall be placed as near as possible to the point where it is to be laid and faced in the proper direction. Suitable skids or blocks shall be left under each pipe, which shall be securely wedged to prevent movement until the pipe is required. In case any pipe receives any indentation or deformation, it shall be returned to the proper shape by satisfactory methods, if such repairs are acceptable; otherwise, it shall be replaced with a new pipe at the expense of the contractor.

Laying Pipe.

SECT. 19.15. The pipe shall be laid accurately to line and grade. It shall be supported either by suitable temporary blocking and wedges or by other approved means, at a sufficient number of points to prevent deformation when filled with water during testing and concreting. If blocking be used, it shall be removed as the concrete work progresses, care being taken to prevent settlement of the pipe.

Field Testing.

SECT. 19.16. When the steel shell at any siphon, or a sufficient length of it, is completed, it shall be tested with water under pressure corresponding to the hydraulic gradient of the aqueduct at this point, and all leaks shall be calked and made tight. The contractor shall furnish the clean water, bulkheads, connections, and all apparatus necessary, and shall be responsible for any damage resulting from the test.

Pipe Held Full during Covering.

Water at full pressure shall be kept in the pipe during the placing of the concrete covering and until the concrete last placed shall

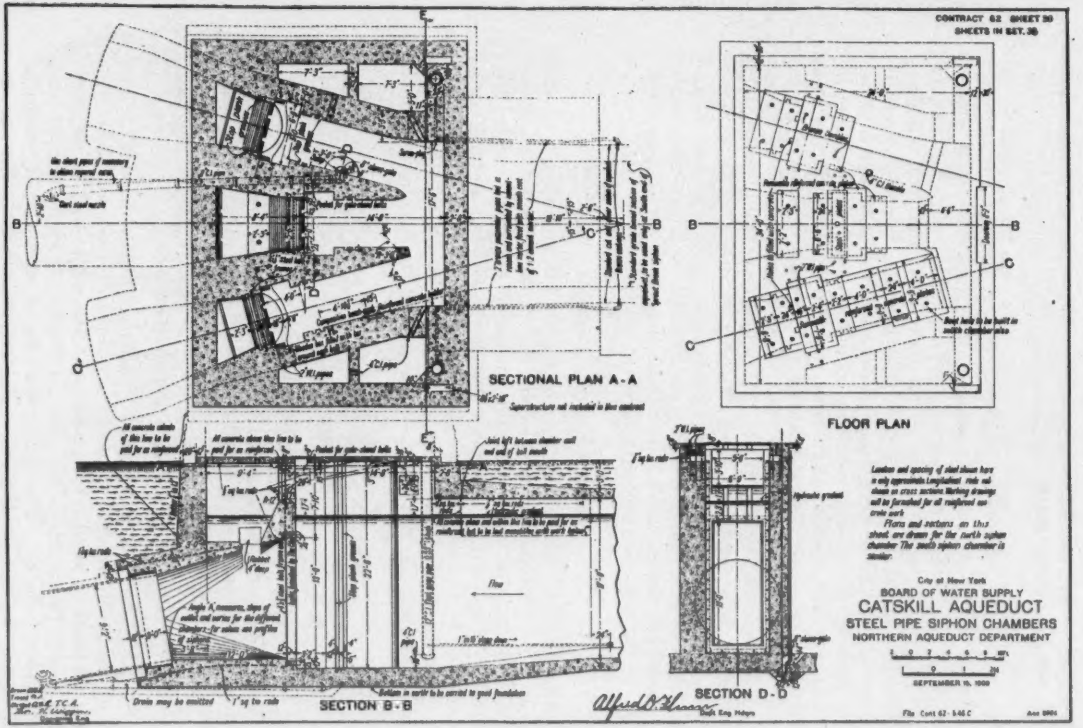


FIG. 4.

STANDARD SIPHON CHAMBER. ONE AT EACH END OF EACH SIPHON EXCEPT SOUTHERLY END OF BRYN MAWR SIPHON.

have set for at least forty-eight hours. The contractor shall then free the pipe from water.

Cleaning and Protection from Rust.

SECT. 19.17. During fabrication into pipe, all steel plates, at each joint where one plate covers another, shall be entirely free from mill scale, from any but light rust, and from all dirt, grease, or other foreign matter. Furthermore, when concrete is placed around, or mortar lining placed within, any section of pipe, the surface of the plate shall be similarly clean. The degree of cleanliness and freedom from scale required shall be such as produced by thorough sand-blasting or thorough pickling; i. e., such that the surface of the steel itself is exposed. The initial cleaning may be done at the mill provided the steel is adequately protected and necessary field cleaning is done. The exposed surface of pipe at the overhead stream crossings at Tongore, Foundry Brook, and Indian Brook siphons shall be given three coats of approved paint, applied to metal cleaned as above specified. Two of the coats shall be applied after erection.

Measurement and Payment.

SECT. 19.18. The quantity to be paid for under each of the items 19 to 24 inclusive shall be the total number of linear feet of 9½-ft. steel pipe shell laid, measured along the axis of the pipe line after laying. The price shall cover all labor and materials necessary to furnish and lay the steel pipe shell, do all cleaning and testing, perform all work on connections not specifically included in Item 25, and complete the pipe in the manner specified.

MORTAR LINING FOR STEEL PIPES.

(Item 26.)

Work Included.

SECT. 26.1. Under Item 26 the contractor shall build a mortar lining inside the steel pipe and cast-iron bell castings as specified, directed or approved.

Description and Proportions.

SECT. 26.2. The lining shall consist of Portland cement and sand, mixed in ordered proportions, probably one part of cement to two parts of sand. The quality of the sand shall be as specified under Items 28 to 30. Reinforcement, if used, will be paid for under Item 27. The lining shall be of substantially uniform thickness throughout the entire circumference except for the un-

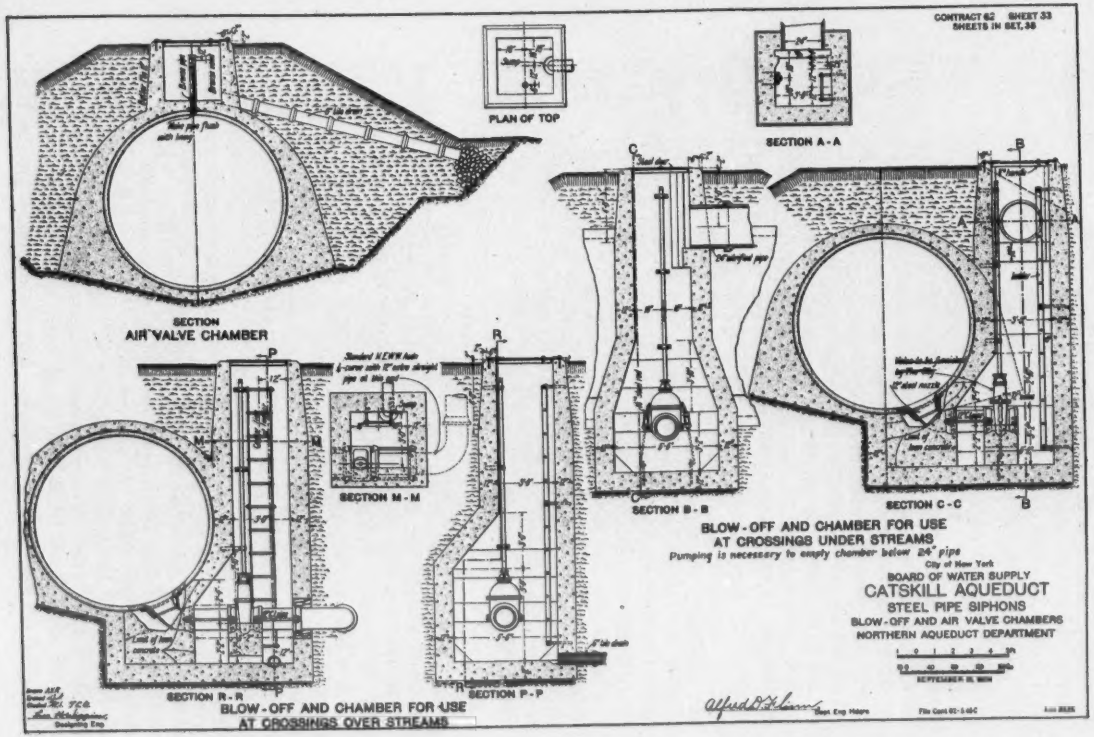

CONTRACT 62 SHEET 33
SHEETS IN SET, 38
PLAN OF TOP
SECTION A - A
SECTION
AIR VALVE CHAMBER
SECTION M - M
SECTION B - B
SECTION C - C
SECTION R - R
SECTION P - P
BLOW - OFF AND CHAMBER FOR USE
AT CROSSINGS UNDER STREAMS
Pumping is necessary to empty chamber below 24" pipe
City of New York
BOARD OF WATER SUPPLY
CATSKILL AQUEDUCT
STEEL PIPE SIPHONS
BLOW - OFF AND AIR VALVE CHAMBERS
NORTHERN AQUEDUCT DEPARTMENT
SEPTEMBER 16, 1914
BLOW - OFF AND CHAMBER FOR USE
AT CROSSINGS OVER STREAMS

FIG. 5.

STANDARD BLOW-OFFS AND AIR VALVE CHAMBERS.

avoidable variations due to lap of the plates, butt straps, and rivet heads. The thickness over the inner course of plates is to be 2 in., that is, the internal diameter of the lining shall be four inches less than the nominal diameter of the steel shell.

Forms.

SECT. 26.3. Forms shall be of steel, or of wood covered with galvanized sheet steel, and shall be especially constructed so as to have sufficient strength and yet be adjustable so as to give a uniform space between them and the shell of the pipe. Great care shall be exercised to secure forms which will leave the surface of the lining perfectly smooth. Forms which give unsatisfactory results after use shall be satisfactorily repaired or replaced. The length of the sections of forms will not be restricted provided satisfactory means are adopted for controlling the uniform thickness of the lining and the correct spacing of the reinforcement, but sufficient sections shall be provided adapted for lining the pipe on curves, where lining shall be placed in sections about 7 ft. long. Each time the forms are used they shall be thoroughly cleaned and then coated with some approved inadhesive substance which will prevent the mortar from sticking to the forms without injuring the mortar. The lining of manhole castings, and of the blow-off elbows to the sockets, shall be monolithic with the lining of the steel shell, and forms shall be so constructed as to permit this method.

Method of Placing.

SECT. 26.4. The lining shall in general be placed by pouring as grout around an internal form, through holes cut in the top of the pipe for that purpose in the manner and at locations specified in Section 19.11. Sections shall be so terminated as to bring a hole at the upper end which shall be arranged as an air vent. The mortar shall be mixed to a thick creamy consistency and allowed to flow into place as uniformly as possible. When the section is filled to the top, the pouring of the grout shall be continued until grout runs from the air vent; then headers of steel pipe shall be screwed into the inlet and outlet holes and filled with grout so as to put a head of at least 4 ft. on the highest part of the section, and these headers shall be kept filled with grout until the grout has set, when the pipe shall be removed and the hole made water-tight by a screw plug. During the pouring of the grout, the form shall be tapped to loosen air bubbles, and a careful watch shall be maintained to prevent leaks. The work shall be so planned that the grout can be poured continuously from start to finish of the section. Any interruption greater than

fifteen minutes, whether due to leaks or any other cause, may be sufficient reason for the rejection of the entire section.

Lining with Plaster.

SECT. 26.5. Should there by any portion of the interior of the pipe which it is impracticable to line by grouting, this portion shall be lined by plastering the pipe with mortar, mixed as specified in Section 26.2. Only skilled masons or plasterers shall be allowed to do this plastering, and a section once started shall be prosecuted until finished, with only such pauses as are necessary for a sufficient setting of a layer to permit the next layer to be placed. Each layer shall be as thick as is feasible to apply, so that as few layers as possible may be necessary. The surface of each layer, except the final one, shall be brushed to thoroughly remove the laitance and then deeply scratched or otherwise satisfactorily treated to give a bond with the succeeding layer.

Removal of Forms.

SECT. 26.6. The forms shall be removed within twelve hours of the time set by the engineer, and the section, if accepted, shall receive immediately such repairs as required, in the manner directed. It is possible that the lower part of the lining will, in many cases, show a sandy surface, and if so, it shall be brushed with enough neat cement wash to fill the pores and no more, and troweled to a smooth finish. Any section not accepted shall be immediately removed by the contractor at his own expense and replaced by acceptable lining.

Prevention of Freezing; Bulkheads.

SECT. 26.7. Suitable bulkheads shall be erected in the pipe to prevent freezing inside the pipe either during the placing of the lining or after its completion. They shall be removed before the completion of the contract, if ordered. Lining shall not be placed in the uncovered pipes over streams during, or within a month before, freezing weather, unless the pipe is satisfactorily protected, and, after lining these portions of the pipe, water shall not be allowed to stand and freeze there.

Measurement and Payment.

SECT. 26.8. For placing the lining in the steel pipe and cast-iron bell castings, the contractor shall receive the price per linear foot of pipe stipulated, the measurement to be made along the axis of the pipe, this price to include all labor and materials necessary to complete the lining in a thorough and approved manner except only that the cement required will be paid for under Item 35 (Portland cement).

REINFORCEMENT OF MORTAR LINING FOR STEEL PIPES.

(Item 27.)

Description.

SECT. 27.1. Reinforcement may be ordered under Item 27 for any part or the whole of the mortar lining. The reinforcing material shall be galvanized steel mesh of a style and weight approved, provided, however, that no reinforcement shall be required of which the lowest price obtainable by the contractor, f.o.b. New York City, exceeds $\frac{3}{4}$ cent per square foot, for lots of 10 000 sq. ft.

Placing.

SECT. 27.2. The reinforcement shall be placed approximately in the center of the mortar lining. The reinforcement may be kept away from the pipe by distorting the reinforcement at frequent intervals, so as to make points projecting toward the pipe. Unless otherwise permitted, small blocks of mortar shall be attached to the reinforcement, for the purpose of keeping it away from the form. Metal shall be lapped at least 6 in. at all longitudinal joints.

Measurement and Payment.

SECT. 27.3. The quantity to be paid for under Item 27 shall be the number of square feet of lining, measured as of a mean diameter 9 ft. 4 in., in which reinforcement has been ordered and placed. This does not include any allowance for lap. The price stipulated shall include the cost of the reinforcing metal, royalty if any, cutting, shaping, bending, wires, clips, mortar, and other devices used for holding the reinforcement in place, or for splicing the strips; and it shall further include any additional expense of forms, tools, appliances, and labor other than the expense that would be required for finishing the mortar lining under Item 26 without reinforcement.

All drawings reproduced as illustrations are for the 9-ft. 6-in. pipes. Corresponding drawings for the other sizes are similar; likewise standard dimensions for rivet and joint details.

All pipes for both contracts were fabricated by the East Jersey Pipe Company, Paterson, N. J., from plates rolled at the Carnegie steel mills near Pittsburgh. After the plates had been bevel-planed on their edges and punched for the rivets, each was bent to proper radius by rolls. This latter operation cracked the mill scale and

loosened it pretty thoroughly, incidentally removing a considerable portion; to remove the remaining mill scale, the rust, and the dirt, the plates were then dipped vertically in a wooden tank containing hot dilute sulphuric acid. This pickling solution was kept at a strength of about 5 per cent. of oil of vitriol, which was approximately 93 per cent. pure sulphuric acid. This bath was maintained at a temperature near 125° fahr., and each plate was in it about fifteen minutes. When removed, the plates were of a uniform, clear steel gray all over, and were at once dipped in clean hot water in an adjacent tank to remove all acid. Fitting and riveting followed promptly. The pipes were made in 15-ft. sections, each of two rings of 7.5 ft. net length. Each ring was of one plate, excepting in the 11-ft. 3-in. pipes, and in pipes made of plates thicker than $\frac{1}{2}$ in., for which two plates were necessary.

As a partial protection against rusting between the times of fabrication and of applying the concrete and mortar, each pipe was given a coat of heavy lime whitewash, made as follows: To one barrel of whitewash (about 50 gallons) there were added 20 pounds of glue; after using this whitewash for a time, about one pound of Portland cement was added for each gallon of whitewash; the glue was dissolved in water before being mixed in the whitewash.

This whitewash was applied with brushes. A spraying machine operated by compressed air was tried but found unsatisfactory. The whitewash did not adhere very well, and, through lack of care in handling the pipes, suffered more or less almost as soon as applied. This temporary coating, however, did not suffer from abrasion or cracking off so much as from exposure to the weather, and even where the whitewash was not disturbed, light rusting occurred. The only places where there was no sign of rusting was around the rivets and at joints, where the whitewash had formed a very thick coating. Consequently, the pipes arrived at the trench with more or less complete coats of light yellow rust; this rust was very uniform on the bared portions of the steel surface, without indications of any tendency to pitting, and has been regarded as unobjectionable.

Delays in laying some of the pipes and further delays in covering them with concrete are permitting the gradual formation of heavier rust, which is being removed, as required by the specifications.

Any remaining whitewash is also removed before applying the concrete or mortar. Ease of removal and absence of serious effects upon the concrete or mortar, if small quantities should not be removed, were among the principal reasons for adopting lime whitewash. Portland cement grout would have adhered more tenaciously, but difficulty of ultimate removal and its probable interference with the good adhesion of the final concrete and mortar coatings were sufficient arguments for forbidding its use. There is room for improvement in this step of our process for protecting steel pipes. Final field cleaning is done in short stretches just in advance of placing the concrete or mortar. Commonly wire brushes alone are used, but for some of the worst places steel scrapers also are employed. Inside some of the siphons the surfaces of the plates have been rubbed with empty cement bags after the wire-brushing.

After the bottom of the trench has been shaped, concrete cradles are built in it to support the pipes so that the invert of the jacket can be placed underneath. Where the trench is in soft ground, cradles have been carried down to good foundation. Their tops are grooved to aid in grouting to insure complete contact of the cement protection with the pipe. In the illustrations a number of these cradles are shown. The size and shape of invert cradles used to date in the Northern Aqueduct Department have varied considerably. The contractor's first choice was for a block 4 ft. wide (transverse to the pipe axis) and 3 ft. long (parallel to the pipe axis). This block was cast using forms with a top radius approximately equal to the pipe radius and of a thickness equal to the normal contract requirements. Trouble was experienced in getting so long a block true to the pipe radius and profile, also with breakage. The contractor next suggested a block 6 ft. wide and 2 ft. long, curved to the pipe radius. This was used only a short time and was then modified by flattening the ends for approximately 1 ft., leaving about 4 ft. of cradle in contact with the pipe (Fig. 6). Some trouble was experienced also in getting this block true to grade, and frequent breakages occurred. Early this season a few cradles were made about 24 in. square and carried 6 in. below the ordinary subgrade of the trench. These cradles were laid to pipe grade and have on the whole been satisfactory. Breakages and chipping of

BRYN MAWR SIPHON.

Rock trench; concrete cradles, showing forms in foreground.

edges have been less, and on account of the greater depth there has been little trouble with undermining. The forms for this type of block are also more easily set. Forms have consisted of light lumber sections and have been set true to line and grade, alternate blocks being set slightly lower to accommodate the outside rings of the pipe. The spacing of the square blocks has been symmetrical with respect to transverse joints, one block under each ring.

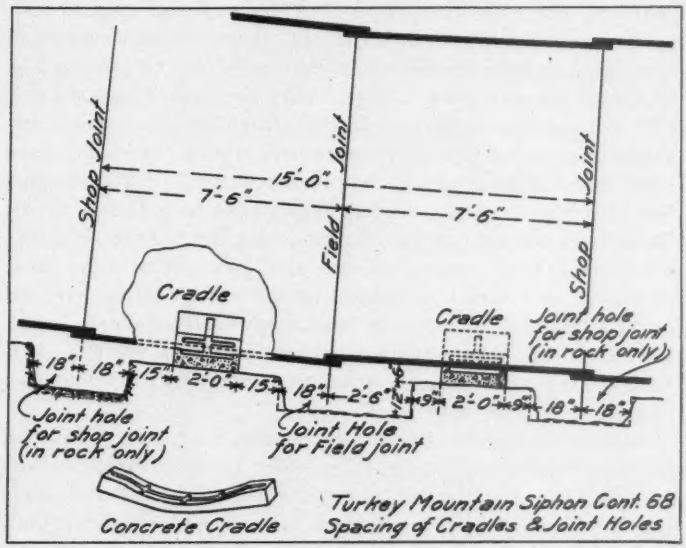


FIG. 6.

TYPICAL ARRANGEMENT OF CONCRETE CRADLES AND JOINT HOLES FOR FIELD RIVETING.

With the other blocks one has been used under each ring, but so spaced as to give 3 ft. to 3 ft. 6 in. calking space in front of the field joints. This is an important detail where wide blocks are used.

In the Southern Aqueduct Department in all cases two cradles have been built under each 15-ft. section of pipe. The size, shape,

and placing of cradles has varied at the different siphons. At three siphons the cradles were constructed with their bearing surfaces molded to the theoretical radius of the steel pipe. At Fort Hill siphon (Fig. 7) the cradle under the inside ring is located with its face 3 ft. 6 in. from the field joint, this cradle being 2 ft. wide and having a bearing surface 6 ft. long molded to the theoretical curvature of the pipe. The cradle under the outside ring is located 2.5 ft. from the field joint, being 3 ft. wide, with the same bearing surface as the one under the inside ring. At Elmsford siphon (Fig. 7) both cradles were made 3 ft. in width, the one under the inside ring being located 2.5 ft. from the field joint, that under the outside ring 2 ft. 3 in. from the field joint. These cradles have a bearing surface of 6 ft., the curvature being somewhat flatter than the theoretical curvature of the steel pipe. A considerable number of cradles have cracked transversely during the process of laying or after the pipe has been placed. Some of these cracks have been caused by the handling of the pipe on the cradles during the process of laying; other cracks have occurred in the sand cuts, due in some cases, probably, to a slight settlement of the cradles, caused by excavation for joint holes, and in other cases, on steep slopes, cracks have been caused by settlement of cradles due to erosion. It is probable that most of these cracks are due primarily to the uneven bearing of the pipe on the cradles.

After the laying and riveting in the ditch have been completed, the pipe is filled with water to hydraulic gradient, inspected, and leaks calked. For this purpose — since the siphon chambers have not been built in time — bulkheads have been placed in the open ends of the pipe and a small riser pipe carried up to the proper elevation, and water kept just spilling over the top of this small pipe or of a small tank. Hydrostatic pressure should be maintained by a small reservoir, with controlled overflow, and not by direct pumping into the steel pipe during the placing and hardening of the concrete jacket. Fluctuations of the head or pulsations due to pumping have caused cracks. While still full of water under normal working pressure, the steel pipe is jacketed with concrete, and this pressure is continued until the concrete has attained considerable strength, or for not less than about two days after the placing of the last concrete, depending upon weather, kind of cement,

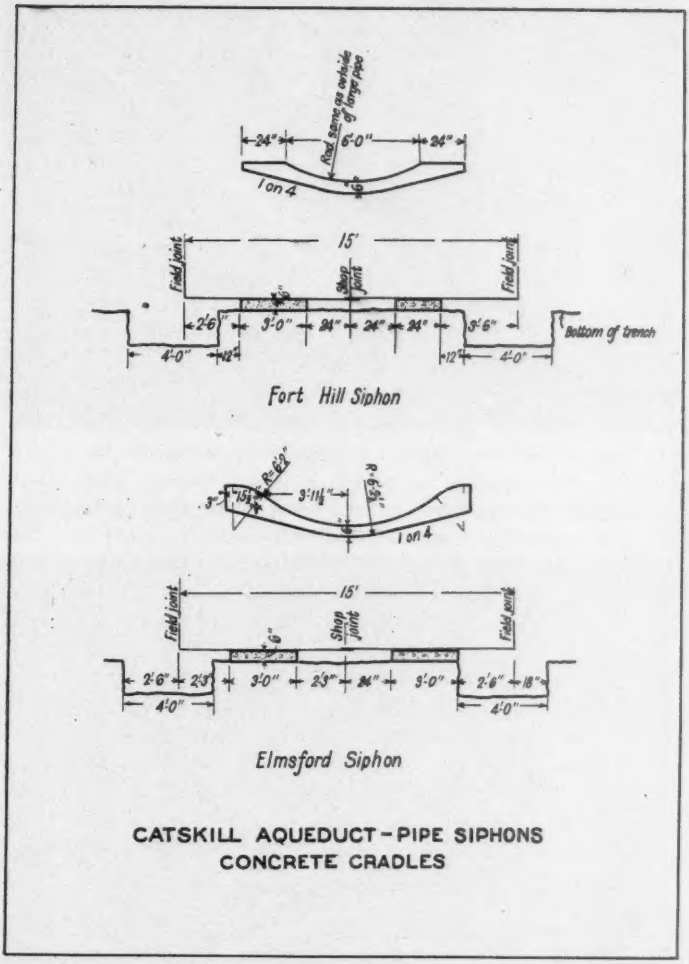

Rod same as outside of large pipe
24"
6'-0"
24"
1 on 4
15'
Field joint
Shop joint
Field joint
2'6"
3'-0"
24"
24"
24"
3'6"
Bottom of trench
4'-0"
12"
12"
4'-0"
Fort Hill Siphon
R=62"
3'-11¼"
R=59"
1 on 4
15'
Field joint
Shop joint
Field joint
2'6"
2'3"
3'-0"
2'3"
24"
3'-0"
2'6"
18"
4'-0"
4'-0"
Elmsford Siphon
CATSKILL AQUEDUCT - PIPE SIPHONS
CONCRETE CRADLES

FIG. 7.

and other conditions. The pipe is then slowly emptied and preparations made for lining. Methods for placing the concrete jacket have not differed essentially from those usual for concrete conduit construction. On one siphon the jacket was placed by three methods in different parts: (*a*) Monolithic (as specified); (*b*) invert first, then remainder; (*c*) invert and side walls to horizontal diameter, then arch. Best contact between jacket and pipe was obtained when the concrete was placed monolithicly. Dumping concrete on to the pipe so as to cause shock should be avoided; a 2-ft. drop is too great.

The average rate of placing the concrete jacket at Hunters Brook siphon was about 130 ft. a week, the maximum week's work being 223 ft.; at Turkey Mountain siphon, the average was about 170 ft., the maximum week's work being 297 ft.; at Fort Hill siphon, average rate about 190 ft., maximum week's work 260 ft. At Hunters Brook and Fort Hill siphons the concrete covering was usually placed in two operations, the invert being placed first. At Turkey Mountain siphon the concrete covering for the greater portion of the siphon was placed in one operation. Last season at Foundry Brook, the best progress in placing the jacket, using concrete mixed by machine, transported and deposited by cableway, was probably 30 ft. of full section per eight-hour shift, or about 50 yd. of concrete. At Indian Brook the best day's work was about the same under similar conditions. There are many factors which influenced this progress, such as method of mixing (at Foundry Brook last year a large part of the mixing was done by hand), method of transportation — cableway, wheelbarrows, or cars — and style of outside forms, — whether steel or wood and conveniences for moving and setting them. On the siphons just mentioned there were two operations in placing the jacket last year, the first including the concrete under the pipe and in the joint holes and thence up to the horizontal diameter, using when necessary steel or wood outside forms. Earth covering was placed immediately after the completion of the concrete jacket, so there has been little chance to observe the tendency to crack. So far as observed, there have been very few cracks in the jackets of any of the siphons built to this date.

For lining the pipes, two distinctly different methods were at

FIG. 1.
FORT HILL SIPHON.
Placing concrete in jacket, with cableway, showing one type of forms.

FIG. 2.
INDIAN BROOK SIPHON.
Wooden forms for mortar lining; completed lining in foreground.

the beginning adopted by the two contractors; on Contract 62 grouting with forms has been employed, and on Contract 68 mortar was applied in the first siphon (Hunters Brook) by means of the "cement gun." Practical difficulties militated against the use of a complete cylindrical form, such as getting around curves, vertical or horizontal; collapsing one section of forms sufficiently to pass forward through another which must remain in place while the grout is hardening; cleaning, lubricating, and inspecting outside of form. Consequently, the invert for a width of about 8 ft. of arc has hitherto been placed first by methods similar to those of concrete sidewalk construction. These wide inverts have generally separated from the pipe along their edges, for one reason or another, so that a piece of steel tape could at places be pushed into the crack for several inches. To obviate this trouble trials are now being made under Contract 68 of inverts 1 ft. to 2 ft. wide.

Under Contract 62, and recently also under Contract 68, wooden forms in panels 2 ft. wide and 15 ft. long (7.5 ft. at curves) adjusted on centers, or wooden ribs, and firmly braced, are used for pouring the remainder of the lining in 15-ft. sections at one operation. The grout is poured from outside the pipe through a $2\frac{1}{2}$-in. wrought-iron pipe secured into a rivet-passing hole. In the Southern Department this pouring pipe is at the downhill end of the section and is long enough to give a head of about 4 ft. on top of the uphill end. A vent pipe is fastened in the uphill rivet-passing hole of the section, the bulkhead forming the end of the lining being placed just below it. For pouring grout the contractor for the northern siphons has always used two mortar boxes set on a temporary staging over the upper end of the section to be grouted. The mortar is mixed to the proper consistence in alternate boxes and is allowed to flow into the pipe through a hole controlled by a sliding wooden gate. All mixing is done by hand, and materials are carefully graded. It generally takes about two hours to fill a section, after which a man is kept on for another hour or two in order to feed in sufficient grout to get the desired consistence. There is a noticeable tendency to get a porous or thin condition at the upper end of the section, near the grouting hole. To avoid this, the riser is removed two or three times during the pouring and the thin material which collects at the top is allowed

to escape. The riser is then put back and grout added until desired results are obtained. In some cases it takes nearly two hours after the main operation to get grout of proper consistence at the foot of the riser. At the finish of the pouring a small pipe is inserted through the large pipe, to permit the escape of the last air while grout is poured through the larger pipe and churned into the small remaining space, to insure complete filling. For the first batches, or nearly up to the horizontal diameter of the pipe, the grout is mixed 1 part cement to 1 part sand, and the remainder about 1 to 2. Lining at Foundry Brook siphon is now being placed at an average rate of about 400 ft. per week, with approximately twelve sets of 15-ft. forms. The contractor's gangs are very efficient at the present time both in handling forms and depositing grout. About two moves per week can be made with each set of forms, and the rate of lining depends on the number of forms and men available.

Engineering Record, July 1, 1911, contains a description of the "cement gun" which is readily available, and so a description of the machine will not be given here. It is shown in one of the illustrations. With this machine the process of lining is to place invert as in the grout method and then build up the arch for the remainder of the circumference in layers placed in rapid succession. Each layer has a rough surface, to which the next adheres well; the first layer on the steel is very thin, and others follow practically continuously at such short intervals that the lining is substantially monolithic. It is impossible to secure a satisfactorily smooth finish with the "cement gun," and so the final layer is floated and troweled before it hardens.

Without further information it is difficult to state the area of mortar lining placed in any interval of time with one cement gun. During the weeks ending July 26, August 2, and August 9, the lengths of pipe lined were, respectively, 204 ft., 254 ft., and 221 ft. For a portion of this time two guns were working, and at times two shifts per day. By both the grouting and the gun methods very smooth interior surfaces are being secured.

In using the cement gun, charges of dry sand and cement mixed in prescribed proportions are placed in the chamber of the machine and then rapidly discharged by air under 50 to 60 lb. pressure

HUNTERS BROOK SIPHON.

Cement Guns on concrete jacket; steel manhole, concrete not yet placed around it.

through a rubber hose; through a parallel hose, joining the first in a special nozzle, water under pressure is discharged so that the sprays of water and of sand and cement are combined. The nozzle pressure is about 30 lb. and so the material is thrown with considerable force against the surface to which it is being applied. This aids in securing the excellent union between the layers. The operative holds the nozzle about 2 or 3 ft. from the surface being coated, moving it back and forth continuously. The flow from the nozzle is controlled by means of lever valves.

One result of the high pressure at the nozzle is that a measurable proportion of the sand bounds off the surface upon which the mixture impinges and falls into the bottom of the pipe, especially when beginning the first layer on the bare steel. This dry material, 1 part cement to $3\frac{3}{4}$ parts sand, by analysis, is clean and is collected for use in making invert. In view of this action, an excess of sand is put into the dry mixture, in order that the lining may be no richer than intended. Another incidental result is that the atmosphere inside the pipe is commonly very dusty, and in order to provide reasonable working conditions for the men, artificial ventilation is resorted to. A third result is that the mortar is less well supplied with water than in the grout, and more attention must be given to keeping the lining moist in order to minimize shrinkage cracks. Failure fully to appreciate the necessity for this moistening in the initial use of the gun was probably contributory to the formation of rather numerous fine cracks. Inevitable temperature changes due to the setting of the cement enhance the tendency to crack. In spite of this untoward circumstance, a satisfactory lining has been secured. After completing one siphon the use of the cement gun was discontinued by the contractor, the reason given being excessive cost. As an aid to preventing cracks and a safeguard against the remote possibility of small pieces of the lining becoming loose and falling, provision was made in both contracts for inserting wire fabric in the mortar, but up to date none has been used.

Absolute adhesion of concrete or mortar to the steel is not being secured at all points, as has been proven by careful sounding with a hammer, but on cutting into hollow-sounding spots the space between the mortar or concrete and the steel has usually been found

almost infinitesimal in width. What effect will such failure to adhere have upon the protective action of the lining? No better reply can be made at present than a brief statement of some experiments at the board's laboratory.

One test was arranged as follows: Six steel plates 8 in. by 16 in., of 12 gage, cleaned by pickling and then by rubbing with emery cloth, were placed horizontally in a galvanized iron tank 18 in. in diameter and 24 in. deep, separated from the bottom by two $1\frac{1}{4}$-in. bars of alberene stone, and from each other by $\frac{1}{2}$-in. wood dowels. The first pair of plates was put in without any protective covering. The second pair had their upper surfaces protected by a slab of cement mortar $2\frac{1}{2}$ in. thick, not in contact with the steel, but separated from it by two metal strips about .04 in. thick. The third pair of plates was protected by cement mortar slabs 2 in. thick, cast directly on the steel, and apparently adhering to it firmly. The tank was then filled with Croton water to a depth of 4 in. above the top of the uppermost mortar slab, and kept filled the entire duration of the test, the water being renewed twice monthly.

After two years' immersion, the plates were taken out and cleaned off by washing with a sponge. The first pair of plates showed heavy corrosion. In numerous places the entire layer of oxide had separated from the steel and formed blisters, leaving the bright steel surface underneath. The second pair of plates showed a very slight corrosion. Most of this washed off, thus indicating a considerable protective influence of the mortar slabs even when separated from the metal by a space of .04 in. When the mortar slabs were removed from the third pair of plates, it was found that a part of the surface of the steel had a distinctly different appearance from the other part. One part was clean and wet; the other part was covered by strongly adhering particles of mortar and was dry, thus indicating that there had been actual adhesion of the mortar only over the latter part of the surface and that the former had been separated by a space large enough for the water to enter. There had, however, been no rusting except at some places near the edges of the wet part of the surface, where apparently the space had been big enough to allow circulation of the water. The water in the rest of the space had evidently been so highly charged with lime that no corrosion could take place.

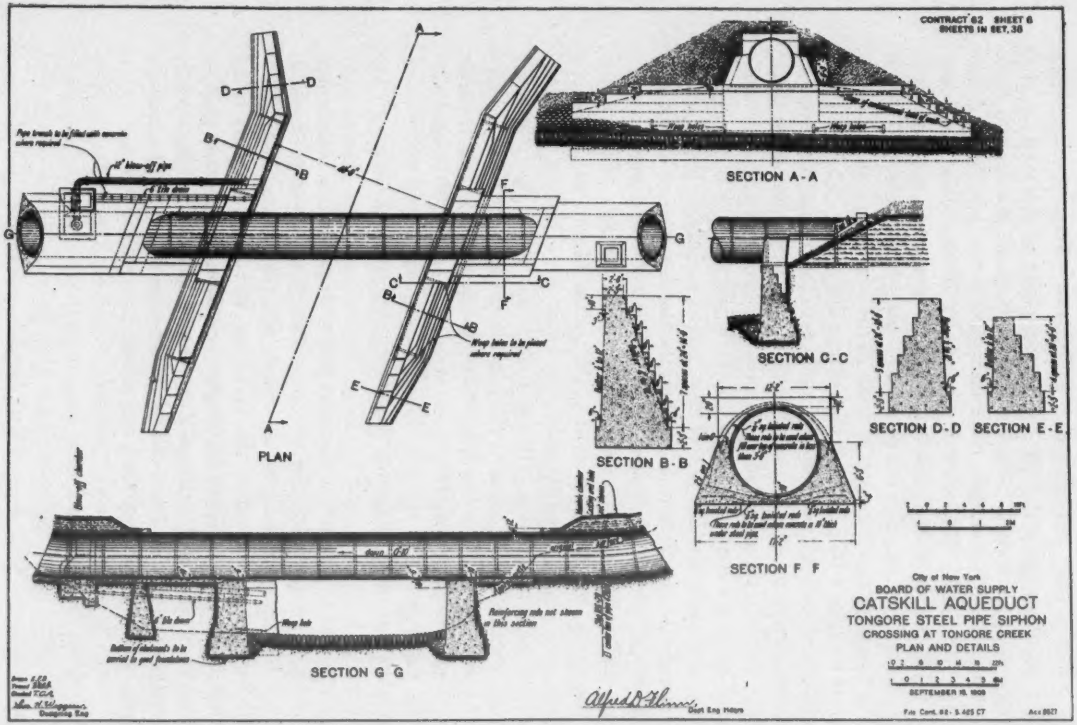


FIG. 8.

TYPICAL OVERHEAD STREAM CROSSING.

Another test was arranged as follows: Four circular slabs $15\frac{1}{4}$ in. diameter and 3 in. thick were made of concrete in proportions 1 cement: 2.7 Jerome Park screenings: 6.3 Jerome Park stone (gneiss) by weight, the consistence of the mix being rather dry. Carefully imbedded in the center of the slabs were four $\frac{3}{4}$-in. round, soft-steel rods spaced 3 in. apart, so that there was at least $1\frac{1}{2}$ in. of concrete in all directions from the rods. When the concrete had set, two of these slabs were immersed in water in two tanks 1 ft. 6 in. in diameter and 2 ft. deep. The other two slabs had two galvanized-iron cylinders $15\frac{1}{4}$ in. in diameter cemented to them, and a head of 20 in. of water maintained on them. The water in the tanks and cylinders was kept at a constant depth and head by the addition of water whenever it was necessary. The slabs subjected to percolation leaked rapidly at first, but became gradually tighter, and during the last few months of the tests there was very little leakage. The tests were conducted in open air, and were subject to the variations in outdoor temperature. The tests commenced July 13, 1907. On March 23, 1909, one year and eight months later, the slabs were broken and rods examined for corrosion. It was found that the protection of the rods by the concrete was perfect in all cases, there being no sign of corrosion on either the black finish of the metal left by the rolls or on the bright ends of the rods exposed in cutting to length with the hacksaw. The concrete when broken was found to be thoroughly saturated, showing that the water had full access to the rods.

The cost to the city of the pipes and their protection is indicated by the contract prices for the important items given in Table 2. It is too early to compute accurately the cost to the contractors. So large a proportion of the jacketing and lining remains to be done that there is room for improvement in methods or gain in facility of operation with present methods, both of which may affect contractor's costs. Parts of the narrative of this type of construction cannot be written for a few years.

TABLE 2.

CONTRACT PRICES FOR STEEL PIPES, CONCRETE JACKET, AND MORTAR LINING.

Description.	Contract Price.	Average of All Bids. (5 bidders.)
Contract 62.		
9 ft. 6 in. steel pipe, $\frac{7}{16}$-in. plate, lap jointed	$31.00 lin. ft.	$35.50 lin. ft.
9 ft. 6 in. steel pipe, $\frac{1}{2}$-in. plate, lap jointed	35.00 " "	41.20 " "
9 ft. 6 in. steel pipe, $\frac{1}{2}$-in. plate, longitudinal seams butt-jointed	40.00 " "	44.80 " "
9 ft. 6 in. steel pipe, $\frac{9}{16}$-in. plate, longitudinal seams butt-jointed	43.00 " "	48.80 " "
9 ft. 6 in. steel pipe, $\frac{11}{16}$-in. plate, longitudinal seams butt-jointed	47.00 " "	55.80 " "
9 ft. 6 in. steel pipe, $\frac{3}{4}$-in. plate, longitudinal seams butt-jointed	50.00 " "	50.60 " "
Mortar lining for steel pipes	2.50 " "	4.90 " "
Reinforcement of mortar lining for steel pipes,	.02 sq. ft.	.03 sq. ft.
Concrete masonry around steel pipes	6.00 cu. yd.	5.85 cu. yd.
Portland cement	1.75 bbl.	1.74 bbl.
Contract 68.		(8 bidders.)
9 ft. 9 in. steel pipe, $\frac{7}{16}$-in. plate, lap jointed	$29.00 lin. ft.	$33.25 lin. ft.
11 ft. 3 in. steel pipe, $\frac{7}{16}$-in. plate, lap jointed	33.00 " "	37.37$\frac{1}{2}$ " "
11 ft. 3 in. steel pipe, $\frac{1}{2}$-in. plate, lap jointed	38.00 " "	42.75 " "
11 ft. 3 in. steel pipe, $\frac{1}{2}$-in. plate, longitudinal seams butt-jointed	46.00 " "	48.75 " "
11 ft. 3 in. steel pipe, $\frac{9}{16}$-in. plate, longitudinal seams butt-jointed	50.00 " "	53.62$\frac{1}{2}$ " "
Mortar lining for 9 ft. 9 in. steel pipe	3.00 " "	3.56$\frac{1}{4}$ " "
Mortar lining for 11 ft. 3 in. steel pipe	3.50 " "	4.04$\frac{1}{2}$ " "
Reinforcement of mortar lining for steel pipe	.02 sq. ft.	.02$\frac{3}{4}$ sq. ft.
Concrete masonry around steel pipe	5.25 cu. yd.	5.78 cu. yd.
Portland cement	1.60 bbl.	1.72$\frac{1}{2}$ bbl.

To sum up, the intended constructional results are being substantially attained. Consequently, with information so far collected, it is reasonable to anticipate a close approximation of the desired measure of protection for the steel pipes. One of the greatest obstacles to ideal results, from the point of view of protection of the steel, is the difficulty of getting the pipes jacketed with concrete and covered with earth soon after delivery. The steel mill and fabricating shop naturally push their operations to

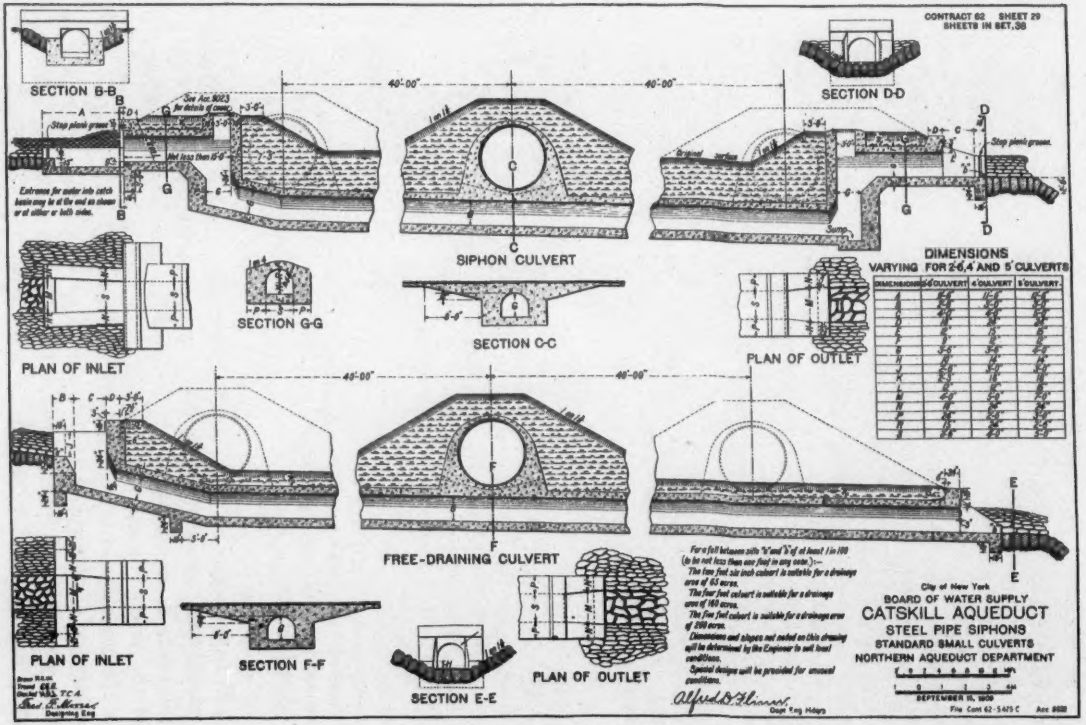


FIG. 9.

ALL CULVERTS ARE BUILT LONG ENOUGH TO ACCOMMODATE FUTURE SECOND AND THIRD PIPE.

completion much more rapidly than the pipe can be laid, tested, and covered.

It is hoped that these pipes will last a hundred years; they may last much longer, barring accidents. Some abuse or unappreciated condition may lead to earlier partial failure, necessitating reconstruction. The gain in smoothness of interior by covering the rivet heads and the plate laps has been computed to so increase the hydraulic capacity that three pipes equal four without lining. The total cost for the siphons with three lined and jacketed pipes is estimated as about the same as for four pipes constructed and coated in the more usual way. Obvious incidental advantages are secured by the more permanent construction.

Engineering operations of the Catskill water works are being directed by *J. Waldo Smith, chief engineer, and Merritt H. Smith*, deputy chief engineer; Robert Ridgway and Frank E. Winsor are department engineers respectively of the Northern and the Southern Aqueduct departments. In immediate charge of the construction of the siphons are Division Engineers John P. Hogan, Alexander Thomson, Jr., and George P. Wood (Northern); George G. Honness, Ernest W. Clarke, and Charles E. Wells (Southern). The drawings and specifications were prepared and many of the preliminary investigations conducted by Senior Designing Engineer Thomas H. Wiggin, and Engineer Inspector Ernst F. Jonson has had charge of inspection at the rolling mills and pipe shops, all under the immediate supervision of the writer. The chief engineer and his personal assistant, Department Engineer Thaddeus Merriman, made many examinations of existing steel pipes which furnished the reasons for seeking a better protection than the usual coatings.

DISCUSSION.

MR. JOHN H. COOK. We have some pipes in the plant at Little Falls, which were coated with cement at the time the plant was built, and we have examined them at different times since and concluded it was pretty good protection, the best we have seen. I know of some steel pipes which were coated with cement wash which are now perhaps twenty years old, and they seem to have

stood up pretty well, although there is now no trace of the cement wash left on the pipe.

MR. WM. R. CONARD. It is usual to use the Rosendale or natural cement for lining pipes, instead of the Portland. I suppose the use of Portland cement in the Catskill Aqueduct work would be more especially because of its quicker setting quality.

THE PRESIDENT. It is to be hoped that the steel manufacturers sometime will find a way of making steel so that it will corrode much less rapidly, whether it is protected or not. I wonder if Mr. Speller can tell us something about the possibilities in that direction?

MR. F. N. SPELLER. That is something we are all working for, but I do not know whether we can hope to make a steel as non-corrodible as you desire. There has certainly been an improvement in this respect in our time, but at present we all have to depend more or less upon protective coatings. If the pipe could always be taken care of in the way which has been described in Mr. Flinn's paper, I do not think the pipe manufacturers would be so busy, for, after the pipe is all gone, you apparently still have a very good conduit.

Talking about pipe materials, I noted what the speaker said about the possibility that wrought iron might have given better service, and I was gratified to hear him cautiously qualify his remarks in the way he did. I can say from our experience that for welded pipe wrought iron would certainly not have given better satisfaction. It is too late in the evening to take time to give my reasons for this statement, but if I had an hour or so I could give you some very tangible and satisfactory evidence on this point. At all events, while fully realizing the importance of the greatest durability, we have discontinued the use of wrought iron without any hesitation as to the steel now being made for pipe being fully equal and probably superior to wrought iron in this respect.

MR. J. WALDO SMITH. I think that Mr. Flinn has given a pretty full description of what has been done. I might add that what led up to the devising of this coating was the entirely unsatisfactory protection furnished by the coatings which had been used since steel pipe had been laid in the East. About twenty-one years ago, I think, the first pipe was laid for the city of Newark,

and careful examinations have been made of the interiors of those pipes from year to year since that time, as well as in other riveted pipes laid at later dates to which all varieties of asphalt coatings have been applied. They all showed serious deterioration in a short time, usually starting with a small blistering which gradually enlarged until great patches of the coating were separated from the pipe. While it is true that this coating would protect the pipe much better than painting, still there were a great many tubercles and a great deal of pitting, and in places where the coating had come off in large patches this pitting was pretty general in a few years. Knowing this condition, and confirming it still further by recent examinations of pipes, the study which Mr. Flinn has so well described was undertaken, with the result which he has shown. In a way it is, perhaps, going back to fifty years ago, to the time of the cement pipe, the only difference, perhaps, being that the present pipe is riveted and calked absolutely tight, whereas in the old cement pipe the tightness depended more particularly on the lining and on the outer cement coating than on the pipe. The pipe was merely shaped and riveted with cold rivets.

THE PRESIDENT. Perhaps the author can tell us something about the acid treatment to remove the mill scale, — how effective it was and about how much per pound it cost.

MR. FLINN. Mr. President, as to the first part of your inquiry, I can answer from observing the process two or three different times. All the pipes I saw, both for the Board of Water Supply and for another public job, pickled in the same way, by the same contractor, the East Jersey Pipe Company, had the mill scale and the other foreign substances removed from the surfaces of the plate completely. I think it would have been practically impossible to have found on the plates I saw any flake of mill scale or any other foreign substance as big as a dime. Those that were seen were easily swabbed off when the pipe was being transferred from the pickling tank to the washing tank; so that the cleansing of the plates, I should say, was thoroughly successful. As to the cost per pound, I haven't the information on which to base that. It might be somewhat difficult to get it.

MR. SPELLER. I would like to comment on the matter of removing the scale. It seems to me a particularly fortunate thing

that so much attention was paid to this matter, as the mill scale is so largely responsible for pitting of iron and steel. Among our experiments we have made a number exposing the same plate, or parts of the same plate, with and without the scale, and found that it makes a very marked difference as to the character of the corrosion whether the plate carries mill scale or does not. I have made some experiments with a plate which had all the scale removed, and a similar piece of steel with only that removed which would accidentally be knocked off in the course of handling the sample; that is, perhaps one tenth of the scale was removed. The corrosion was measured by the loss in weight. In the case where there was considerable scale on the surface, there was deep pitting; and in the other case where the surface was clean, the corrosion was so uniformly distributed that very little damage was done, although the average loss in weight per unit of area was about the same in both cases. I think this is a point that engineers might well bear in mind in considering the protection of iron and steel pipes, viz., the benefit derived from removing the scale before applying any protective coating.

THE PRESIDENT. I think Mr. Speller's remarks upon this point are very important. In some estimates made in our office, some time ago, we allowed a quarter of a cent a pound for treating pipe in this way, but from subsequent developments I am well satisfied that the actual cost is much less than it is figured.

MR. FLINN. I might add one word for the benefit of those who have not had any experience with pickling of steel plates, and that is that a weak solution, a comparatively inexpensive solution, is much more effective in securing a proper cleaning than a strong solution; and a little heat, a temperature of 120° to 125° fahr., greatly accelerates the action of the acid. I should like to know whether Mr. Speller has had similar experience.

MR. SPELLER. We use a 5 per cent. solution of sulphuric acid at about 180° fahr. We think those are the most effective conditions.

A BRIEF DESCRIPTION OF THE GLOUCESTER WATER WORKS.

BY JOHN W. MORAN, SUPERINTENDENT.

[*Read September 13, 1911.*]

The water supply of this city consists of three artificial storage reservoirs, Dikes Brook, Wallace Brook, and Haskell Brook; deriving their supply from well-wooded and uninhabited watersheds, they are free from pollution and furnish a very good quality of water.

The area of Dikes Brook Reservoir is 58 acres; the elevation of the surface, 102 ft.; the watershed area, exclusive of reservoir area, is 376 acres; maximum depth, 24 ft. 6 in.; average depth, 13 ft.; and the storage capacity is 275 000 000. gal.

Wallace Brook Reservoir is 24 acres in area; the elevation of the surface, 63 ft.; the watershed area, 164 acres; maximum depth, 20 ft. 6 in.; average depth, 8 ft.; and the storage capacity is 63 000 000 gal.

Haskell Brook Reservoir is 62 acres in area; the elevation of the surface, 113 ft.; watershed area, 350 acres; maximum depth, 39 ft.; average depth, 23 ft.; and the storage capacity is 475 000 000 gal., of which 285 000 000 only is available for use.

The total watershed area of the three reservoirs is 1 034 acres; the total available storage capacity is 623 000 000 gal., and the consumption at the present time is about 500 000 000 gal. a year.

The estimated daily yield of the three reservoirs in a year of average rainfall is 1 500 000 gal., and the average use in 1910 amounted to 1 343 639 gal. per day.

The water is conveyed from Dikes Brook Reservoir to the pumping station by about a mile of 14- and 16-in. pipe; from Wallace Brook Reservoir to the pumping station by 400 ft. of 14-in. pipe, and from Haskell Brook Reservoir to the pumping station by about 2½ miles of 20-in. pipe. On the line of pipe between Haskell Brook Reservoir and the pumping station there is a high elevation

in the road for a distance of 600 ft., which is 8½ ft. below high-water mark in the reservoir, and it was necessary to lay the pipe 12 ft. below the surface of the road in order to utilize the upper 17 ft. or 285 000 000 gal. of storage.

The pumping station is situated on Magnolia Avenue, near the junction of Essex Avenue, which is on the street-car line of the Essex and Beverly Street Railway. The pumping plant consists of one Knowles duplex compound condensing engine having 16-in. and 30-in. steam cylinders, 16-in. water plungers, a 24-in. stroke, and a capacity of 3 000 000 gal. in twenty-four hours; one Barr pumping engine, vertical, cross-compound, fly-wheel type with steam cylinders 22-in. and 42-in. in diameter, differential water plungers 13½ in. and 19 in. in diameter with a stroke of 30 in. and a normal capacity, at a piston speed of 200 ft. per minute, of 4 000 000 gal. in twenty-four hours; two horizontal tubular boilers each 72 in. in diameter, 130 3-in. tubes 16 ft. long, working pressure 100 lb.; one air pump for charging air chambers; and one electrical generating set for lighting purposes.

The water is delivered from the reservoirs direct to the pumps at a pressure ranging from 12 lb. to 30 lb. per sq. in. on the suction pipe when the pumps are running, and is pumped to a distributing reservoir on Bond's Hill at an elevation of 184 ft. and of about 3 000 000 gal. capacity. Two force mains lead to the reservoir, one being a 16-in. cement lined and the other a 20-in. cast-iron pipe. The two supply mains leading from the reservoir to the city are an 18-in. cement lined and a 20-in. cast-iron pipe, both being laid along Western Avenue through a pipeway, which also accommodates a 12-in. gas main of the Gloucester Gas Light Company, under the canal at the Cut, so called.

The office and stable is on Procter Street, a short distance from City Hall. The stable equipment consists of two horses and three automobiles, one a Maxwell 22-h.p. gasoline runabout, one 1 500-lb. White gasoline truck, and one Cadillac one-cylinder runabout. The blacksmith shop, storehouse, and pipe yard, with a spur track from the Boston & Maine Railroad, are on Arthur Street.

The first works were built by George H. Norman in 1884. In 1895 an act was passed by the legislature authorizing the city of Gloucester to supply itself and its inhabitants with water for

fire, domestic, and other purposes and to take by purchase or otherwise the water from any source within the limits of the city not already taken or purchased by the Gloucester Water Supply Company; also to take water from the Chebacco Lakes in the towns of Essex, Wenham, and Hamilton, with the right to supply the town of Essex, if they so desired, with water for fire, domestic, and other purposes. The act further provided that if the Gloucester Water Supply Company shall notify the mayor of the city that it desires to sell its property, and if within one year from the act the city shall by a majority vote to purchase the water works, it shall thereupon become the property of the city; and in case the city and company shall be unable to agree upon the value of the property, the Supreme Judicial Court shall appoint three commissioners who shall determine the fair value of the property; such value to be estimated without enhancement on account of future earning capacity, or future good-will, or on account of the franchise of the company.

The city took possession of the plant on October 1, 1895, the property of the company at that time consisting of Dikes Reservoir, Wallace Reservoir, pumping station, one pump, two boilers, Bond's Hill Reservoir, house and land on Wallace Court, office building and stable on Procter Street, 23¾ miles of cement-lined pipe from 4 in. to 18 in., and 5½ miles of pipe of less diameter than 4 in., making a total of 29 miles of main pipe; 181 hydrants, 192 gates, 2 120 services, 6 fountains, 14 standpipes for filling watering carts, and 46 meters.

Three commissioners were appointed to determine the price to be paid by the city, and the hearings opened December 20, 1897. The value of the plant as testified to by the experts employed by the city was $300 000, while those employed by the water company placed the value at $1 300 000. The price settled upon by the commissioners to be paid by the city for the plant was $576 035. The interest amounted to $203 965, and the legal and other expenses were over $100 000 more, making the cost of the original plant to the city about $900 000.

The city since 1895 has added a new engine room and pumping engine, new boiler room and boilers, Haskell Brook Reservoir, pipeway under the canal, and purchased land enough on Bond's

Hill for a new distributing reservoir; extended mains to Riverdale, Annisquam, Bay View, Lanesville, Eastern Point, Bass Rocks, and other places; relaid 6½ miles of cement-lined pipe with cast-iron pipe, and extended 29 miles of cast-iron pipe.

The main pipe in use November 30, 1910, was 29 miles of cast-iron pipe from 4 in. to 20 in., 17⅜ miles of cement-lined pipe from 4 in. to 18 in., 22½ miles of pipe less than 4 in. in diameter, 14 miles of which is for summer use and is laid near the surface of the ground and is shut off and drained before freezing weather. The total main pipe is 68.43 miles. There are now 326 hydrants, public and private; 546 valves, 4 530 services, 343 meters, 49 standpipes for filling watering carts, and 11 fountains.

The cost of the works November 30, 1910, was $1 463 936.29, the bonded debt was $1 078 000, with interest at 3½ per cent. and 4 per cent. The annual cost of maintenance is about $23 000.

In past years the reservoirs have during the winter and early spring filled up full to the flow line, or nearly so; but this year, when pumping was started from the Haskell Reservoir, this pond was 7 ft. below the flow line, and Dikes Reservoir was also 7 ft. low at the same time, while the Wallace Reservoir, from which we had been pumping all winter, was 15 ft. below the flow line and practically empty, only 5 ft. of water remaining in it.

The water commissioners, considering the seriousness of the situation, established a regulation prohibiting the use of lawn sprinklers and allowing the use of hose by hand only. By strictly enforcing this regulation, and by the highway department discontinuing about three fourths of the water usually used for street sprinkling by substituting oil, 25 000 000 gal. less were pumped in July and August of this year than in the corresponding months of last year. At the present time, Dikes Brook Reservoir is 4 ft. low, Haskell Reservoir is 14½ ft. low, and Wallace Reservoir is nearly full.

DISCUSSION.

THE PRESIDENT. I have been very much interested in hearing about the Gloucester Water Works. I remember that when I was here professionally, fifteen or sixteen years ago, there was a somewhat different story told about the quality of the water

from what we have heard this morning, and that one particular complaint was that the water contained short lobsters. I would like to ask Mr. Moran whether he still finds them.

MR. MORAN. A few in cold weather.

THE PRESIDENT. Are you still troubled with tastes and odors, or do you use copper sulphate to hold the organisms down?

MR. MORAN. The only trouble we have now is from Wallace Brook Reservoir, which is a shallow basin, and we do not use the water from that pond in the summer. We have no trouble with the other ponds.

MR. GEORGE BOWERS. When you shut off the summer supply to the cottages, how do you get rid of the water in the pipes? Can you draw it all off so that they are empty, or do they freeze up in the winter?

MR. MORAN. The pipes for summer use are laid near the surface, and just before cold weather they are drained and then they are ready for the spring. The reason we use so much of that kind of pipe is that it would be very expensive to reach the summer residences with a deep pipe. The board is relaying some of these pipes every year, and in course of time we hope to replace them all by deep pipe.

THE PRESIDENT. How much do you charge for the summer residences, in proportion to the amount charged for houses which are supplied the year round?

MR. MORAN. The summer people pay the annual rate. There is no discount.

A MEMBER. What is the size of the surface pipe?

MR. MORAN. Two inches.

MR. WILLIAM F. SULLIVAN. What is the ordinary rate for a summer house?

MR. MORAN. I could not say what the average is, because some of the houses have a number of bathrooms, four or five. The charge for an ordinary house with one bathroom and hose is $23. There is an extra charge of $8 for each additional bathroom.

PURIFICATION OF SALT WATER.

BY ROBERT SPURR WESTON, SANITARY EXPERT, BOSTON, MASS.

[*Read September 13, 1911.*]

The city of Gloucester, Mass., is well known as one of the great fish markets of the world. Here come the trawlers from the Grand Banks, the hand-liners from the Georges, and the mackerel seiners from the waters nearer shore. Here are discharged cargoes of fish, some of which is marketed in a fresh state, but most of which is cured, salted, pickled, smoked, or canned, and finds a market over a wide territory.

By far the most important part of the industry is the preparation of the cod and other salt fish for the market. The other fish which are handled like the cod, in dressing and curing commercially, are the haddock, cusk, hake, and pollack. It is not the writer's purpose to describe this work, but Bulletin No. 133 of the Bureau of Chemistry, United States Department of Agriculture, will prove most interesting to those who desire to study the matter. The author of this pamphlet, Mr. A. W. Bitting, inspector in the Bureau of Chemistry, describes in great detail the study of the industry which he made in 1910. The most important feature of this investigation was a bacteriological study of the causes of the so-called "reddening" of salt codfish. The author states that codfish and some other salt-cured fish are subject to spoilage when exposed to a temperature above 65° F. This spoilage is manifested by the surface of the fish turning red and emitting a foul odor.

The reddening of the codfish is an old difficulty in the industry, but formerly was not of the commercial importance that it is at the present time, for then the business was limited to the cooler months of the year, and such spoilage as did occur in summer was taken as a necessary loss. The improved methods of packing have made the product more attractive to the general consumer, and have created a demand for the product throughout the year, and, at the same time, have made it more perishable and of higher cost.

The loss which occurred was, therefore, more keenly felt, and that which was once thought to be a necessity is now considered preventable.

Mr. Bitting found that the so-called reddening was due to the growth of organisms on the fish, especially a mold-like fungus (*Oidium morrhuæ*), and one of the causes for the growth of these organisms at Gloucester was the impure salt water used for washing the fish. Mr. Bitting writes as follows:

"It is generally agreed among the fish packers that sea water is much to be preferred for washing the fish and making the pickle. Well water or fresh water is said to cause some changes which are objectionable. At the beginning of this study it was understood that the sea water used was obtained at some distance from the plants and that it was pure. In the course of the examination of the fish, organisms were found which were recognized as being ordinarily associated with polluted water, and this led to an investigation as to the cause of their presence. The water used by the packers is from the Gloucester Harbor, and is taken only a few feet from the end of the docks. This harbor is long and narrow, surrounded on three sides by the city, and the surface water from the streets drains into it. Many private sewers and a few fairly large ones discharge into this basin, besides numerous closets upon the docks and those connected with the cottages that overhang the water. All the brine from the butts, the water washing from the fish, and more or less gurry are added to this volume of impurities. The result is a very high bacterial content and the presence of forms that would condemn the water for any domestic use. Tests were made of the water at all the packing plants and at various places in the harbor beyond the breakwater and in the open sea. There was a marked variation in the number of organisms present in the different places and at different stages of tide. In no case could the water be said to be pure within the inner harbor. The long, narrow shape of the harbor and the position of the breakwater preclude the movements of the tide from changing the water each day. A short distance beyond the breakwater, however, and at all points along the eastern coast, pure water was obtained, and this should be used."

Furthermore, the Bureau of Chemistry reported that B. coli had been found on some of the salt fish marketed.

As a result of those reports, it was obvious to many of the fish packers that something must be done to improve the water

supply, and one of the writer's clients installed a mechanical filter, using sulphate of alumina as a coagulant. Partly because of the poor design of the filter itself, and chiefly because of the inadequate provisions for coagulation, the effluent was not at all satisfactory; large numbers of bacteria were present and B. coli were abundant therein.

Accordingly, it was decided to replace this mechanical filter with a slow sand filter of the usual type. This example has been followed by others. The first of these filters, with a capacity of 5 000 gallons per hour, was built for Cunningham & Thompson, of Gloucester. It consists of a wooden tank containing three feet of sand supported upon a one-foot, graded gravel layer. The effluent from the filter discharges through a floating orifice-regulator into the clear-water basin, whence it is pumped to the plant by means of a motor-driven pump controlled automatically by a float-switch; another pump, also controlled by a float-operated automatic switch, supplies water to the filter.

When the filter was designed, the writer could find no precedent to guide him. On general principles he believed that bacteria could be removed from salt water more readily than from fresh water because of the well-known tendency of salt water to coagulate certain kinds of colloidal matter discharged into it. A search of the literature was fruitless, and, aside from a few aquariums where salt water was filtered for use in observation tanks, no examples of salt-water filters could be found on record. It is for the recording of the results of the operation of this filter that this paper is written.

The raw sea water taken from the outer harbor, at the Cunningham & Thompson works, is much purer than the water of the inner harbor. It is, however, polluted with sewage discharged at the southwesterly side of the city, at a point less than 1 000 ft. distant from the intake. A partial analysis of the water was made on November 14, 1910, and the results, showing a slight degree of pollution, are as follows:

Constituent.	Parts per Million.
Nitrogen as free ammonia.....	0.108
„ „ albuminoid ammonia.....	0.112
„ „ nitrites.....	0.007

Bacteria at 20° C.....Liquefied plate.
„ „ 37° C.....95 per c.c.
B. coli.....Present.

The filter was put in operation in May, and since then bacteriological examinations of the influent and effluent have been made with the following results:

Date of Examination.	Total Bacteria per c.c.					
	Growth at 20° cent.		Growth at 37° cent.		B. Coli per c.c.	
	Unfiltered.	Filtered.	Unfiltered.	Filtered.	Unfiltered.	Filtered.
1911						
May 17	1250	350	340	75	8	0.03
„ 24	875	290	192	65	6	0.0
June 6	560	65	75	18	4	0.0
„ 20	665	130	340	62	5	0.0
„ 29	320	49	130	19	7	0.0
July 19	560	75	290	45	4	0.0
Aug. 7	160	42	134	28	2	0.0
Sept. 13	195	35	130	20	7	0.0

The above results show the remarkable removal of coli by the filter, even during the first month of operation, and, furthermore, a reasonable bacterial efficiency. Since June 20 the results, at no time bad, have been very good. It is believed, however, at present writing that, while the removal of B. coli is excellent and satisfactory, the aging of the filter is as necessary for the removal of other bacteria as is the case when fresh water is filtered.

A second filter is now under construction for the Gorton-Pew Fisheries Company. The water to be filtered is from the inner harbor near the landing place of the Boston and Gloucester steamers, and is much more highly polluted than that from the outer harbor. For this reason provision has been made to aërate the water before filtration and to filter at a lower rate than in the previous case.

Two filters, each 21 ft. square, a clear-water basin 32 ft. long by

10 ft. wide by 10 ft. deep, and a pump house 10 ft. square, as well as all the accessory parts, are included in a reinforced concrete structure, about 47 ft. by 36 ft. in area. Nearly the whole of the structure is above ground and rests upon a ledge. The regulating chambers are built within the clear-water basin. These, as well as the filters, are covered with a wooden house, while the clear-water basin and pump house are covered with a concrete-slab roof. The filters are of the usual type and contain 4 ft. of sand supported upon 1 ft. of graded gravel, underdrained with split tiles.

Water from the harbor will be pumped through the aërators into the filters. Filtered water will flow into the regulating chamber inside, from which it will be pumped through a floating regulator consisting of a float and submerged orifice, which, in turn, will discharge into the clear-water basin, whence the water will flow either by gravity to the wharves below or by pumping to an elevated tower tank.

It is estimated that this filter has a capacity of 100 000 gal. in twenty-four hours at a rate of 5 000 000 gal. per acre per diem, or about 80 000 gal. at a 4 000 000-gal. rate.

DISCUSSION.

THE PRESIDENT. This is a very interesting paper, gentlemen. It shows the application of an old process to an entirely new field.

MR. FRANK L. FULLER. I would like to ask Mr. Weston if the organisms in this polluted salt water are similar to those in polluted fresh water.

MR. WESTON. The organism to which objection is made is the ordinary sewerage bacteria, the B. coli. That is the only one which has been criticised, but I imagine that the other sewerage bacteria must be present.

MR. W. H. RICHARDS. I would like to inquire if the filter takes out any appreciable quantity of the salt. I remember that, in the instructions for first aid to the wounded, salt water is referred to as an antiseptic, and I wondered whether the salt water would not have to be more heavily loaded with sewage than fresh water in order to have the same number of germs in it.

MR. WESTON. I don't quite grasp Mr. Richards's question, but I can say that, so far as I know, salt water has a tendency to precipitate organic matter. Mr. Clark made a series of studies in connection with the proposed Charles River Basin in Boston, some years ago, and those studies showed conclusively that sewage would be precipitated by salt water. Of course there would be a tendency to throw down the bacteria in the sewage with the precipitate. As to whether salt water itself is a disinfectant to any great extent, that is a matter which we don't know very much about.

For the first half hour or so the filter reduced the salt, but after that and at the present time there is no reduction in the salt content.

THE PRESIDENT. I remember that Prof. William Ripley Nichols made experiments in the filtration of salt water many years ago with reference to that point, and his finding was that no salt whatever was removed by the process.

MR. ELBERT E. LOCHRIDGE. It is very interesting to me to see the way in which this system of filtration has been applied to salt water, and for a purpose which is of as much value from the point of view of health, in all probability, as the filtration of some other kinds of water. It is simply along the line of keeping water used in the preparation of food supplies as pure as the water that we use for drinking.

PROCEEDINGS.

NANTASKET BEACH, MASS., June 14, 1911.

The June meeting of the New England Water Works Association was held at Paragon Park, Nantasket Beach, Mass., to-day. Vice-President Collins in the chair.

The following members and guests were present:

MEMBERS.

S. A. Agnew, G. A. P. Bucknam, James Burnie, T. J. Carmody, M. F. Collins, Albert S. Glover, R. K. Hale, F. E. Hall, Willard Kent, G. A. King, C. F. Knowlton, A. R. McCallum, A. E. Martin, W. E. Maybury, John Mayo, F. L. Northrop, C. E. Peirce, G. H. Snell, G. T. Staples, W. M. Stone, D. N. Tower, L. J. Wilber, F. B. Wilkins. — 23.

ASSOCIATES.

Anderson Coupling Company, by Charles E. Pratt; Builders Iron Foundry, by A. B. Coulters; Chadwick-Boston Lead Company, by A. H. Brodrick; Allyne Brass Foundry Company, by B. T. Beardsley; Darling Pump and Manufacturing Company (Ltd.), by H. H. Davis; The Fairbanks Company, by A. W. Farwell; W. H. Gallison Company, by P. J. Lynch; Hersey Manufacturing Company, by Albert S. Glover; Lead Lined Iron Pipe Company, by T. E. Dwyer; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by J. G. Lufkin; Neptune Meter Company, by H. H. Kinsey; Norwood Engineering Company, by C. E. Childs; Rensselaer Valve Company, by F. S. Bates and C. L. Brown; A. P. Smith Manufacturing Company, by F. N. Whitcomb; Thomson Meter Company, by E. M. Shedd; Water Works Equipment Company, by H. M. Heim; Henry R. Worthington, by Samuel Harrison and E. F. Nye. — 20.

GUESTS.

Miss Inez Stryker, Everett, Wash.; Mrs. C. F. Knowlton, Melrose, Mass.; Fred E. Sharp, Whitman, Mass.; Mrs. T. J. Carmody, Miss Katherine Sullivan, Holyoke, Mass.; Mrs. John J. Sullivan, Bangor, Me.; Charles E. Johnson, North Andover, Mass.; Mrs. C. E. Peirce, East Providence, R. I.; Mrs. Fred S. Bates, Troy, N. Y.; Mrs. L. J. Wilber, Campello, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mrs. W. E. Maybury, Mr. and Mrs. R. D. Wetherbee, Braintree, Mass.; F. W. Matthers, Boston, Mass.; George

McKay, Jr., Philadelphia, Pa.; F. B. Wilkins, Woonsocket, R. I.; Mrs. H. H. Kinsey and Mrs. E. M. Shedd, Boston, Mass.; Mrs. B. T. Beardsley and Miss H. M. Beardsley, Detroit, Mich.; John Kelly, water commissioner, Braintree, Mass.; and I. S. Holbrook, of the *Engineering Record*, New York, N. Y. — 23.

The Secretary presented applications for membership from the following, properly endorsed by the Executive Committee:

T. J. McCarthy, city engineer, Holyoke, Mass.; Henry R. Buck, consulting engineer, Hartford, Conn.; Arthur W. Jepson, manager Bristol Water Company, Bristol, Conn.; Charles T. Treadway, president Bristol Water Company, Bristol, Conn.; Charles E. Johnson, superintendent Board of Public Works, North Andover, Mass.; Frank L. Anders, city engineer, Fargo, No. Dak.; Raymond W. Parlin, resident engineer, Washington County Water Company, Hagerstown, Md.

The Secretary was directed to cast the ballot of the Association in favor of the applicants, and he having done so they were declared elected.

The Thirtieth Annual Convention.

Gloucester, Mass.,
September 13, 14, 15, 1911.

The Thirtieth Annual Convention of the New England Water Works Association was held at Gloucester, Mass., September 13, 14, and 15, 1911.

The headquarters of the Association were at the Hawthorne Inn, East Gloucester. The sessions of the convention were held in the Casino adjoining the Inn, where also were provided accommodations for the exhibits of associates.

The following members and guests were present:

Honorary Members.

Frederic P. Stearns. — 1.

Members.

S. A. Agnew, M. N. Baker, C. H. Baldwin, L. M. Bancroft, F. A. Barbour, F. D. Berry, C. R. Bettes, F. E. Bisbee, A. E. Blackmer, J. W. Blackmer, E. C. Brooks, George Bowers, James Burnie, C. E. Chandler, T. J. Carmody,

W. F. Codd, M. F. Collins, W. R. Conard, J. H. Cook, H. R. Cooper, E. R. Dyer, E. D. Eldredge, J. L. Dower, G. H. Finneran, A. D. Flinn, F. L. Fuller, T. C. Gleason, A. S. Glover, W. B. Goentner, J. M. Goodell, J. W. Graham, F. E. Hall, D. A. Hartwell, W. C. Hawley, Allen Hazen, D. A. Heffernan, W. R Hill, George Holtzmann, F. T. Kemble, Willard Kent, G. A. King, J. J. Kirkpatrick, C. F. Knowlton, B. C. Little, E. E. Lochridge, F. H. Luce, T. J. Lynch, T. J. MacCarthy, Daniel MacDonald, T. H. McKenzie, A. E. Martin, W. E. Maybury, F. E. Merrill, G. F. Merrill, J. W. Moran, F. L. Northrop, A. E. Pickup, A. A. Reimer, W. H. Richards, Robert Ridgway, G. A. Sanborn, P. R. Sanders, A. L. Sawyer, J. E. Sheldon, J. Waldo Smith, G. H. Snell, F. N. Speller, G. A. Stacy, G. T. Staples, W. F. Sullivan, H. L. Thomas, R. J. Thomas, S. F. Thomson, J. L. Tighe, D. N. Tower, C. H. Tuttle, J. H. Walsh, R. S. Weston, G. C. Whipple, J. C. Whitney, L. J. Wilber, G. E. Winslow, I. S. Wood, and L. C. Wright. — 84.

ASSOCIATES.

Anderson Coupling Company, by Chas. E. Pratt; H. L. Bond Company, by F. M. Bates and G. S. Hedge; Builders Iron Foundry, by D. W. Bartlett, A. B. Coulters, and F. N. Connet; Chapman Valve Manufacturing Company, by H. L. DeWolfe; Darling Pump and Manufacturing Company (Ltd.), by H. H. Davis; The Fairbanks Company, by A. W. Farwell and W. D. Cashin; Gamon Meter Company, by C. A. Vaughan; Glauber Brass Manufacturing Company, by Sam. Davis and S. S. Freeman; Hart Packing Company, by Horace Hart; Hays Manufacturing Company, by C. E. Mueller and T. J. Nagle; Hersey Manufacturing Company, by A. S. Glover and H. D. Winton; Lead Lined Iron Pipe Company, by T. E. Dwyer and E. J. Stark; Ludlow Valve Manufacturing Company, by H. F. Gould and G. A. Miller; Charles Millar & Son Company, by C. F. Glavin; H. Mueller Manufacturing Company, by O. B. Mueller, G. A. Caldwell, and A. C. Pilcher; National Meter Company, by C. H. Baldwin, J. G. Lufkin, and H. L. Weston; National Water Main Cleaning Company, by D. H. Buell; Neptune Meter Company, by F. A. Smith, H. H. Kinsey, R. D. Wertz, and T. D. Faulks; Pittsburg Meter Company, by T. C. Clifford, V. E. Arnold, and F. L. Northrop; Rensselaer Valve Company, by C. L. Brown; Ross Valve Manufacturing Company, by William Ross; A. P. Smith Manufacturing Company, by T. F. Halpin, F. N. Whitcomb, and D. F. O'Brien; Standard Cast Iron Pipe and Foundry Company, by W. E. Dodds; Standard Water Meter Company, by A. S. Merrill; Thomson Meter Company, by E. M. Shedd; Union Water Meter Company, by F. E. Hall; Waldo Brothers, by H. E. Browne; Water Works Equipment Company, by W. H. Van Winkle and H. N. Hein; R. D. Wood & Co., by C. R. Wood; and Henry R. Worthington, by Samuel Harrison, E. F. Nye and George Carr. — 54.

GUESTS.

Mr. F. L. Cole, Andover, Mass.; Mrs. A. A. Reimer, East Orange, N. J.; Mrs. D. N. Tower, Cohasset, Mass.; Mrs. Thomas J. Carmody, Miss C. Ryan,

Holyoke, Mass.; Mrs. W. J. Wilber, Brockton, Mass.; Master Neddie Eldredge, Onset, Mass.; Harold H. Sinclair, Bangor, Me.; Mrs. George Holtzmann, Schenectady, N. Y.; F. W. Dinwiddie, Gardner, Mass.; Mrs. E. E. Lochridge, Springfield, Mass.; Thomas P. Taylor, Boston, Mass.; Mrs. C. R. Bettes, Far Rockaway, N. Y.; Mrs. O. B. Mueller, New Rochelle, N. Y.; Miss Joan M. Ham, Boston, Mass.; Mrs. F. H. Luce, Woodhaven, N. Y.; Miss Lillian G. Dillaway, Mrs. C. F. Knowlton, Melrose, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mr. and Mrs. James P. Bacon, Cambridge, Mass.; E. F. Hughes, Boston, Mass.; Mrs. L. M. Bancroft, Reading, Mass.; Mrs. R. J. Thomas, Mrs. George Bowers, James G. Hill, Lowell, Mass.; Mrs. I. S. Wood, Providence, R. I.; Marshall G. Richey, Isaac Poor, F. S. Camlin, and F. A. Hall, Haverhill, Mass.; C. A. Goodhue, Thompsonville, Conn.; Mrs. Henry D. Winton, Miss Laura J. Dillaway, Mrs. F. L. Fuller, Clifford D. Winton, Paul J. Dedrickson, Wellesley Hills, Mass.; Mrs. Robert Ridgway, Poughkeepsie, N. Y.; Mrs. William F. Codd, Nantucket, Mass.; Mr. and Mrs. J. J. Desmond, Lawrence, Mass.; Mrs. George H. Snell, Attleboro, Mass.; A. J. Provost, I. S. Holbrook, of *Engineering Record*, Henry A. Johnston, of *Fire and Water Engineering*, A. R. Murphy, New York City; Mr. and Mrs. J. B. Longley, Lewiston, Me.; Mrs. George E. Winslow, Waltham, Mass.; Mrs. S. E. Thomson, New Paltz, N. Y. — 50.

Wednesday, September 13, Morning Session.

The convention was called to order at 11 o'clock by Allen Hazen, the President, and Mayor Isaac Patch, of Gloucester, was immediately presented. He spoke as follows:

Gentlemen of the New England Water Works Association, — On behalf of the citizens of Gloucester I wish to extend to all of you a very cordial welcome to our city. This is the first time that your Association has met in Gloucester, and I trust that you will enjoy yourselves on this picturesque point of Cape Ann as much as we enjoy having you with us, and I hope you will decide to come again.

I congratulate you on your organization, and on this, your thirtieth annual convention. You meet each year to discuss the various problems which confront you from time to time on the subject of water works, which is of vital interest to all of us. After looking over the program which has been presented to me, I feel sure that the papers which are to be read will be very beneficial and instructive to all, and we are indebted to you for coming here this year and giving us the results of your experiences.

Our water department is managed by three commissioners

elected by the municipal council, consisting of five members, including myself. It has been a separate organization since the city acquired the plant from a private company in 1895. The council appropriates the money and the commissioners spend it. We have been fortunate in having as manager of our water department a very able and thoroughly equipped man, who has been at the helm ever since our city took charge, and he has performed valuable service to the city of Gloucester.

I think I would better not weary you by telling you what I know about water, as this has been a dry year in Gloucester in more senses than one. However, there is one thing that I wish to state, and that is that wherever you go, you cannot find any better water than that which the people of Gloucester drink every day.

While you are attending this convention, I want you to be sure to have a good time during your stay with us, and I trust that you will become better acquainted with our city with all its natural beauty.

Gloucester was first settled in 1623, and the colony which established itself on the land which is now the city park across the harbor had for its object the pursuit of the fisheries, which have been carried on here ever since, with the possible interruption of a few years in the early part of the seventeenth century. It is no wonder, then, that the name of Gloucester is known everywhere.

You are to have the experience of a fishing trip on Friday, which I am sure you will enjoy, although it will not be similar to a trip to the Grand Banks. If you have the time, you would be interested in looking through the packing houses where the fish is prepared for market. You would then be able to witness for yourselves the method of conducting our fishing industry on shore, and it would be apparent to you why Gloucester leads all in its excellently prepared fish products.

Gloucester's attractive location and picturesque scenery make it the great and popular summer resort that it is, and people come from all parts of this country to spend their summers with us.

I do not wish to take any more of your time this morning except to say again that we are extremely pleased to have you with us, and hope that you will thoroughly enjoy yourselves and will come again soon.

THE PRESIDENT. In behalf of the Association I thank you most warmly, Mr. Mayor, for the cordial invitation and welcome to the city. I know that we shall want to visit the packing houses, and I, for one, remembering former visits, want to "box the Cape" and visit those great granite quarries where the paving stones that we see used all over the United States are cut out and split. We got some idea of the picturesqueness of Gloucester on our way through the narrow crooked streets from the station, features of an older civilization than are exhibited, perhaps, in our more recently built cities, and we shall renew here some of our ideas of early history. I assure you that the members of the Association are very glad to be in Gloucester.

The first business in order was the election of members. The Secretary read the following names of applicants, all of whom had been approved by the Executive Committee.

Active: William A. Carstensen, Winthrop, Mass., water commissioner; Stephen E. Keefer, Berkeley, Cal., engaged in general and consulting practice covering water works, sewage disposal plants, land reclamation, and hydro-electric power development; J. Albert Robinson, Canton, Mass., superintendent fire records, National Fire Protection Association; John L. Dower, Hartford, Conn., president board of water commissioners; W. S. Cramer, Lexington, Ky., chief engineer in charge of the water system of the city of Lexington; George T. Evans, Manchester, Mass., superintendent; J. B. Longley, Leominster, Mass., superintendent.

On motion of Mr. Lewis M. Bancroft, the Secretary was directed to cast the ballot of the Association in favor of the candidates named, and he having done so they were declared by the President to be duly elected members of the Association.

Frederic P. Stearns, chairman of the Committee on Yield of Drainage Areas, submitted the following report:

SEPTEMBER 9, 1911.

MR. WILLARD KENT, *Secretary New England Water Works Association,*
715 TREMONT TEMPLE, BOSTON, MASS.

Dear Sir, — The Committee on Yield of Drainage Areas held a fully attended meeting on March 8, 1911, when it discussed at length the scope of the

work of the committee and discussed in much detail the nature of the inquiries which should be made in order to obtain the desired information.

Mr. H. K. Barrows was appointed secretary, and he has prepared, in accordance with suggestions made at that meeting, circular letters and blank forms which have been submitted to each member of the committee and which will soon be sent to members of the Society and others having valuable information as to the yield of streams. The remarkable drought of 1911, as it affects water supplies depending upon the storage of water from comparatively small drainage areas, leads the committee to conclude that no inquiry would be complete which did not include information as to the run-off to the end of the present drought, and for this reason the sending out of the circulars and blanks has been purposely delayed.

Very truly yours,

FREDERIC P. STEARNS, *Chairman.*

On motion of Mr. Robert J. Thomas it was voted that the President appoint a Nominating Committee to bring in a list of officers for the year 1912. The President subsequently appointed as members of the committee, Edwin C. Brooks, John C. Whitney, William F. Sullivan, E. E. Lochridge, and W. C. Hawley.

John W. Moran, superintendent of the Gloucester Water Works, read a paper giving a brief description of the works.

AFTERNOON SESSION.

Mr. W. H. Richards, engineer and superintendent of the Water and Sewer Department, New London, Conn., presented a paper entitled "Coming Efficiency in Water-Works Management." The paper was discussed by Messrs. A. E. Martin, A. L. Sawyer, T. J. Carmody, Arthur E. Reimer, M. N. Baker, W. C. Hawley, George A. King, and Frank L. Fuller.

Mr. Robert Spurr Weston, sanitary expert, Boston, Mass., read a paper entitled "The Filtration of Salt Water," in which he described the process of purifying water used in the curing of fish at Gloucester. The paper was discussed by Mr. Frank L. Fuller, Mr. W. H. Richards, and Mr. E. E. Lochridge.

EVENING SESSION.

THE PRESIDENT. In the new work for the increased water supply for New York City it is necessary to do a great deal of construction in the watersheds of the present supply of New York,

Yonkers, and Peekskill, and perhaps some other places. The measures that have been taken to prevent the pollution of these supplies by the workmen engaged on the construction of the new work have been very novel and, I believe, absolutely unprecedented. It has seemed to me most desirable that these measures should be described to the members of this Association and to be made a matter of record. The chief engineer of the work suggested that Mr. Provost, who has charge of most of this work, should give the description. I have the pleasure of introducing to you Mr. Provost.

Mr. A. J. Provost, New York City, then read his paper entitled "Protection of New York's Water Supply from Pollution during Construction Work." He was followed by Mr. Robert Ridgway, department engineer, Board of Water Supply, New York City, with a paper on "Hudson River Crossing of the Catskill Aqueduct." Both these papers were illustrated by stereopticon views.

THURSDAY, SEPTEMBER 14. MORNING SESSION.

THE PRESIDENT. The first matter on the program this morning is the reading of a paper by Mr. Hardolph Wasteneys, Rockefeller Institute for Medical Research, New York City. Mr. Wasteneys is unfortunately unable to be here this morning, being in the South on a trip which could not be postponed. He was formerly chemist of the Brisbane Water Works, and was there at the time of my visit. The results which had been obtained in treating the water were unusual and interesting, and I think have an application to a good many reservoir waters in this country. I want to say just a few words about the character of this water, so you will understand what the problem was.

Brisbane is in the edge of the tropics. A large part of the reservoir is not very deep, and vegetation grows with great luxuriance. Whenever the reservoir is drawn down, vegetation grows on the sides and forms a mass of material that men are working on cutting out constantly. If it was not for that, the reservoir would almost fill up with this vegetation. A water of that type, which is very much like the Ludlow water at Springfield, only more so, and like the Goose Creek water at Charleston, and like the waters on the Isthmus of Panama, is devoid of oxygen, because the decompo-

sition of the organic matters takes it up, and it ordinarily contains ferric iron. It is a water which is impossible of being successfully treated by sand filters as ordinarily constructed, and it is also impossible to treat it by mechanical filters as ordinarily constructed and operated. The problem was the treatment of this kind of water, a water which is sometimes available and is the only water which can be used where water is wanted.

Mr. Robert Spurr Weston then read the paper, which was entitled "A Short Account of Some Purification Experiments with a Surface Water in Queensland, Australia." The paper was discussed by Mr. Weston, Mr. E. E. Lochridge, and the President.

THE PRESIDENT. The next order of business is "Topical Discussion." Has any one any matter to bring up? The Secretary tells me that he understood there was to be some discussion as to the increase of water consumption during the recent hot weather.

MR. FRANK L. FULLER. At Wellesley we have a ground water supply, and although the consumption was greater during the hot months this summer than ever before, we still had plenty of water, perhaps partly due to some extra wells which we drove last fall and winter. We used less water on the streets than usual; I presume, on account of the use of Tarvia and oil and various other materials.

MR. ALFRED D. FLINN. I understand that the normal consumption of Croton water, which is about 340 million gallons per day, has been forced down to about 260 millions, in spite of the unusually warm weather, by the influence of newspaper agitation and warnings to the people. This has involved, however, a curtailment of legitimate uses of water as well, probably as a reduction of the waste in manufacturing places and apartment houses and private dwellings.

The President then showed about fifty views of California, including water works and other subjects, taken from negatives made by himself a few weeks ago, with a running description covering the present sources of supply for the city of San Francisco, owned by the Spring Valley Water Company, and the proposed sources in the Sierra Mountains.

Mr. William F. Sullivan, at the request of the President, in the

absence of Herman M. Peck, civil engineer, Hartford, Conn., its author, read a paper entitled "Organization and Efficiency."

Evening Session.

The Secretary read the following list of applicants for membership, approved by the Executive Committee:

Active: Clifford M. King, Sandusky, Ohio, chief engineer of the Department of Public Service of the city of Sandusky, in charge of the Water-Works Division; Harold H. Sinclair, Bangor, Me., assistant superintendent; Frank L. Cole, Andover, Mass., superintendent; Richard L. Tarr, Gloucester, Mass., foreman water works.

Associate: Grip Coupling Company, Ware, Mass., manufacturers of pipe specialty fittings; *The Engineering Record*, New York City.

On motion of Mr. John C. Whitney, the Secretary was instructed to cast the ballot of the Association in favor of the applicants named, and he having done so they were declared duly elected members of the Association.

Mr. Alfred D. Flinn, department engineer, Board of Water Supply, New York City, read a paper entitled "Protection of Steel Pipes in the Catskill Aqueduct." The paper was illustrated by stereopticon views. Mr. John H. Cook, Mr. W. R. Conard, Mr. F. N. Spiller, and Mr. J. Waldo Smith took part in the discussion.

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association was held at Paragon Park, Nantasket Beach, Mass., on Wednesday, June 14, 1911.

Present: Vice-President Michael F. Collins, William E. Maybury, Richard K. Hale, and Willard Kent.

Applications of the following-named persons were approved and recommended to the Association for election to membership.

T. J. McCarthy, city engineer, Holyoke, Mass.; Henry R. Buck, consulting engineer, Hartford, Conn.; Arthur W. Jepson, engineer Bristol Water Company, Bristol, Conn.; Charles T. Treadway, president Bristol Water Company, Bristol, Conn.; Charles E. Johnson, superintendent Board of Public Works, North Andover, Mass.; Frank L. Anders, city engineer, Fargo, No. Dak.; Raymond W. Parlin, resident engineer Washington County Water Company, Hagerstown, Md.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., Thursday, July 13, 1911, at 11 o'clock A.M.

Present: Vice-President Michael F. Collins, William E. Maybury, Lewis M. Bancroft, Richard K. Hale, Robert J. Thomas, and Willard Kent.

Mr. Sherman of the Committee on Annual Convention being called away by business engagements, it was

Voted: That Mr. William E. Maybury be and hereby is made a member of that committee in place of Mr. Sherman.

Voted: That the annual convention of this Association be held in Gloucester, Mass., on the 13th, 14th, and 15th of September next.

Voted: That Mr. F. N. Whitcomb, of the A. P. Smith Manufacturing Company, be and hereby is made the Committee on Associates' Exhibits at the annual convention to be held in September next.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., Tuesday, August 15, 1911.

Present: Vice-President Michael F. Collins, Lewis M. Bancroft, Richard K. Hale, John J. Kirkpatrick, Leonard Metcalf, Robert J. Thomas, and Willard Kent.

Mr. Maybury, of the Committee on Annual Convention, reported satisfactory arrangements for holding the convention at the Hawthorne Inn, Gloucester, Mass.

After discussion of desirable topics for future literary programs, the meeting adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at the Convention Hall, Hawthorne Inn, Gloucester, Mass., September 13, 1911.

Present: President Hazen, and members Irving S. Wood, William E. Maybury, Lewis M. Bancroft, Robert J. Thomas, and Willard Kent.

Seven applications for membership were received and recommended for admission, namely:

For membership, William A. Carstensen, water commissioner, Winthrop, Mass.; Stephen E. Kieffer, consulting engineer, San Francisco, Cal.; J. Albert Robinson, fire protection engineer, Boston, Mass.; John L. Dower, president board of water commissioners, Hartford, Conn.; George T. Evans, superintendent Gloucester Water Works, Gloucester, Mass.; W. S. Cramer, chief engineer water works, Lexington, Ky.; J. B. Longley, superintendent water works, Lewiston, Me.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association, at Hawthorne Inn, Gloucester, September 14, 1911.

Present: President Hazen, and members Irving S. Wood, William E. Maybury, Lewis M. Bancroft, J. Waldo Smith, Robert J. Thomas, and Willard Kent.

Five applications were received and recommended for admission, namely:

For membership: Harold H. Sinclair, assistant superintendent water works, Bangor, Me.; Richard L. Tarr, foreman Gloucester Water Works, Gloucester, Mass.; Clifford M. King, chief engineer Department Public Service, Sandusky, Ohio; Frank L. Cole, superintendent water works, Andover, Mass.

For associate membership: Grip Coupling Company, Ware, Mass.

Adjourned.

WILLARD KENT, *Secretary.*

OBITUARY.*

WALTER HERBERT SEARS, for about five years chief engineer of the Aqueduct Commissioners, in charge of the extensions of the Croton water supply of the city of New York, died October 7, 1911, at his home in Plymouth, Mass.

Mr. Sears was born in Plymouth, in 1847, and graduated from the Massachusetts Institute of Technology in 1868. The following year was spent on Prospect Park, Brooklyn, and the second year in the office of Mr. John B. Henck, civil engineer, Boston. From 1872 to 1874 Mr. Sears was chief engineer constructing water works for Winchester, Mass.; from 1875 to 1879 he held a similar position in charge of preliminary surveys and construction of water works for Pawtucket, R. I.; in the year 1880–1881, as chief engineer, he constructed water works for Stillwater, Minn.; and in 1882–1883 an extension of the water-works system of Winchester, Mass. In 1883–1884 he was an assistant engineer of the American Bell Telephone Company, placing wires underground in the vicinity of Boston and Washington. As resident engineer he constructed a new water supply for Beverly, Mass., in 1885 to 1887, and the following two years were spent as chief assistant engineer of the East Jersey Water Company, at Paterson, N. J. In 1891 he was chief assistant engineer on the additional water supply of Rochester, N. Y. For the succeeding ten years Mr. Sears was engaged in general engineering practice, including renewal of the water-supply systems of Plymouth and Lincoln, Mass., and plans for a new water supply for Grand Rapids, Mich. In 1903 he became department engineer under the Commission on Additional Water Supply, appointed by Mayor Low to investigate Catskill and the other water projects for New York City, Mr. Sears having charge of the Catskill department. Following this engagement Mr.

* Memoir prepared by Alfred D. Flinn.

Sears was resident engineer for the Northern New Jersey Flood Commission, with offices at Paterson, N. J. In 1904 he became division engineer of the Croton River Division of the Aqueduct Commissioners and had charge of work in the vicinity of Katonah, N. Y. From August 1, 1905, to January 9, 1906, he was acting chief engineer, and from the latter date to April 1, 1910, chief engineer of the Aqueduct Commissioners; during this period the Cross River reservoir was completed and the Croton Falls reservoir construction begun and carried nearly to completion. During the latter part of his engagement Mr. Sears was taken ill and was unable to return to active work.

He was a member of the American Society of Civil Engineers from October 5, 1904. Mr. Sears was elected a member of the New England Water Works Association on September 13, 1899.

MEMBERSHIP.

ADDITIONS.

(July 1 to November 1, 1911.)

MEMBERS.

Carstensen, William A.
Water Commissioner, 24 Lincoln Terrace, Winthrop, Mass.

Cole, Frank L.
Superintendent Board of Public Works, Andover, Mass.

Cramer, W. S.
Chief Engineer and Superintendent Water Works, Lexington, Ky.

Dower, John L.
President, Board of Water Commissioners, Hartford, Conn.

Evans, George T.
Superintendent Water Works, Manchester, Mass.

Kieffer, Stephen E.
Consulting Engineer, Mechanics Institute Building, San Francisco, Cal.

King, Clifford M.
Chief Engineer, Department Public Service, Sandusky, Ohio.

Longley, J. B.
Superintendent Water Works, Lewiston, Me.

Robinson, J. Albert
Superintendent Fire Records, National Fire Protection Association, 87 Milk Street, Boston, Mass.

Sinclair, Harold H.
Assistant Superintendent Water Works, Bangor, Me..

Tarr, Richard L.
Foreman, Gloucester Water Works, Gloucester, Mass.

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Barnes, William T.
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Bush, Edward W., C. E.
Chief Engineer, Lyme, Conn.

Fuller, William B.
Care Mexican Northers Power Company, Ltd., Santa Rosalie, Chihuahua, Mexico.

Glendenning, H. J.
Care Sewerage Commission, Milford, Mass.

Gregory, John H.
Rudolph Hering & John H. Gregory, Consulting Engineers, 170 Broadway, New York, N. Y.

Letton, Harry P.
213 E. Hanover Street, Trenton, N. J.

Perkins, John H.
114 Marshall Street, Watertown, Mass.

Philbrick, Burton G.
Eaton-Philbrick Laboratories, 444 Market Street, San Francisco, Cal.

Priest, George W.
General Manager, Lloyd & Richards, Inc., Point and Erie Streets, Camden, N. J.

Saville, Charles
Assistant Engineer, 170 Broadway, New York, N. Y.

Taylor, Edwin A.
186 Ford Street, Portland Ore.

Van Winkle, Walton
Salem, Ore.

Young, Henry A.
Civil Engineer, Room 340, Produce Exchange Building, New York, N. Y.

DEATHS.

McCallum, A. R.
Superintendent Water Works, Whitman, Mass. September 4, 1911.

Sears, Walter H.
Plymouth, Mass. October 7, 1911.

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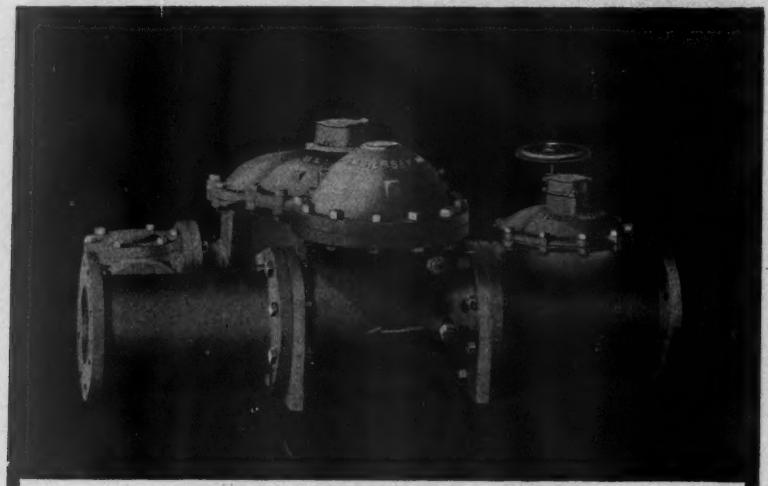

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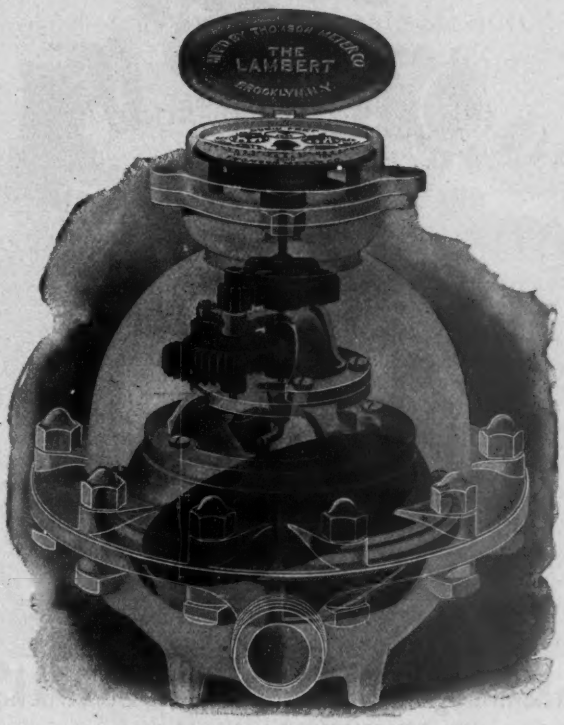

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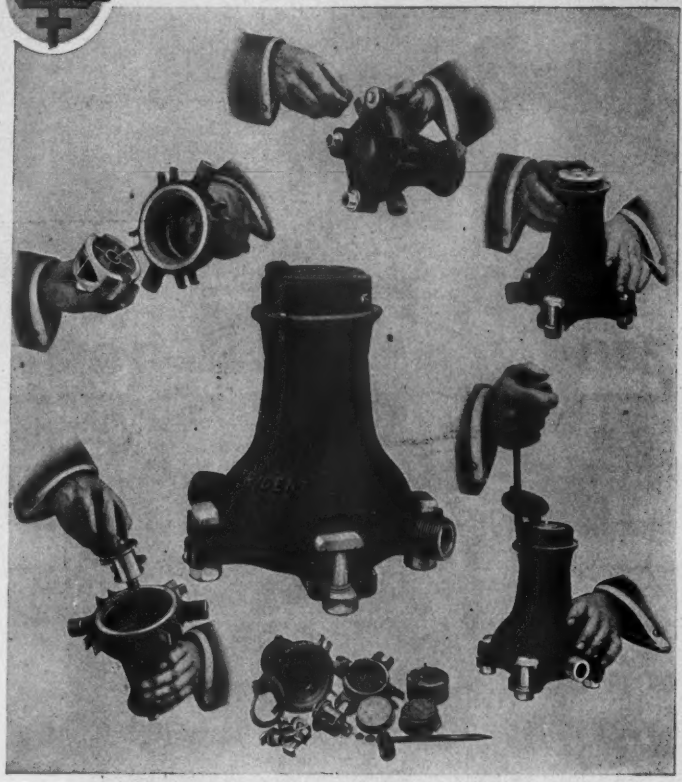

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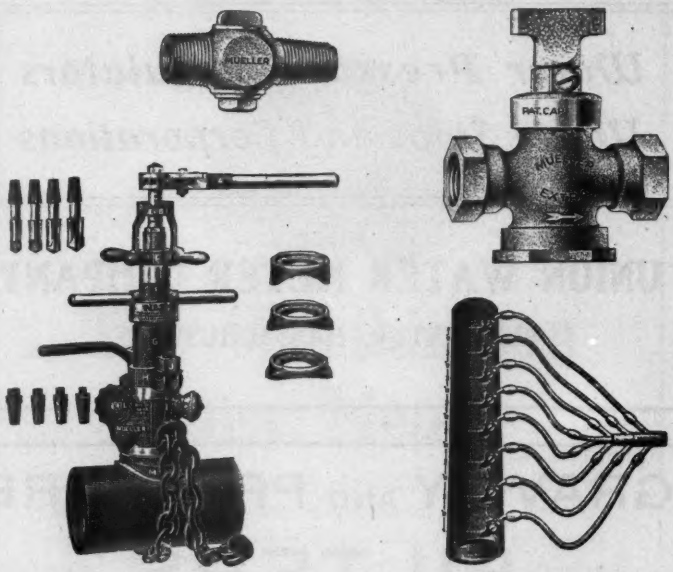

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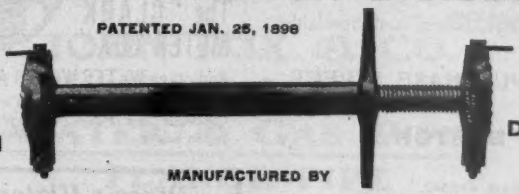

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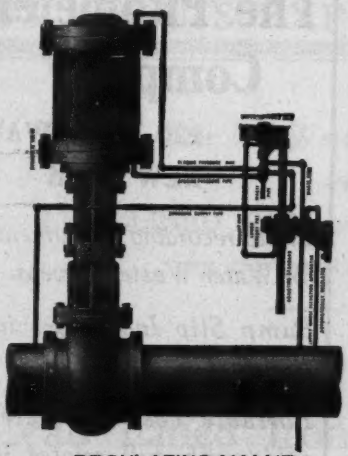

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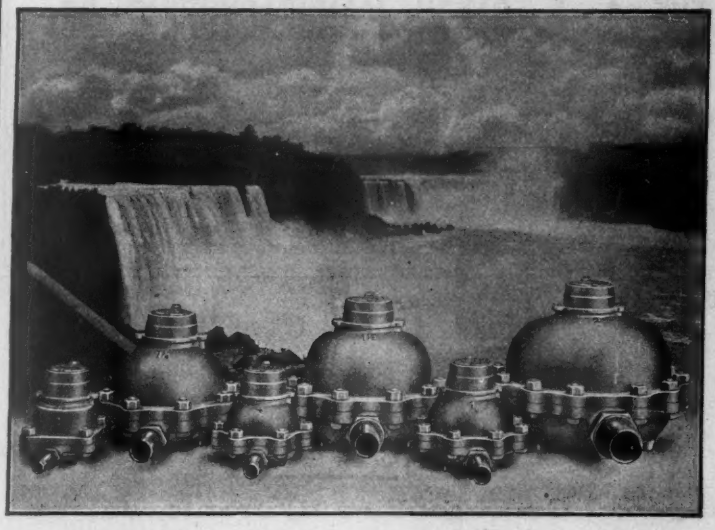

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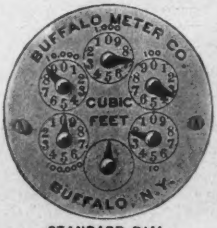

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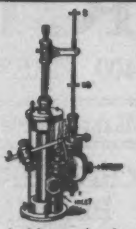

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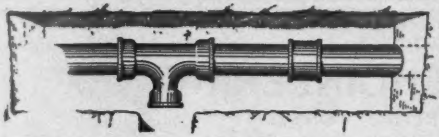

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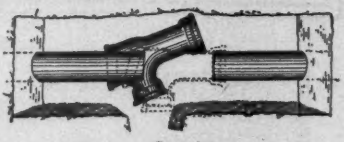

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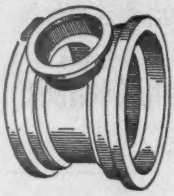

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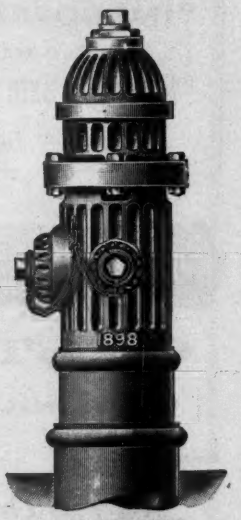

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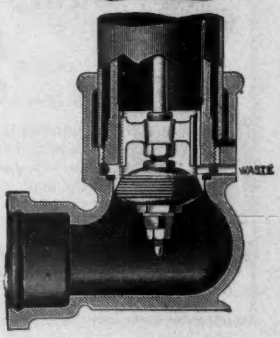

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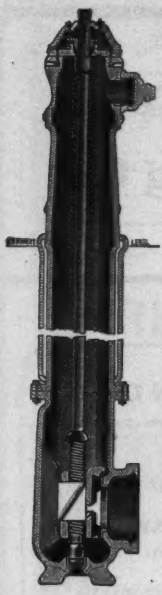

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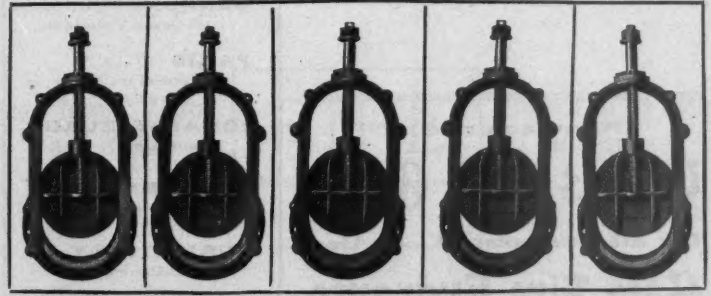

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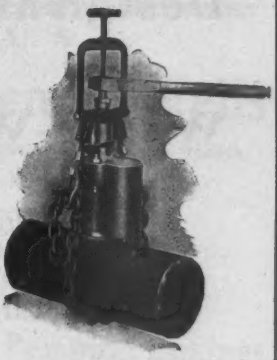

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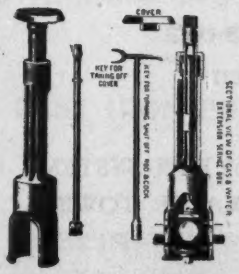

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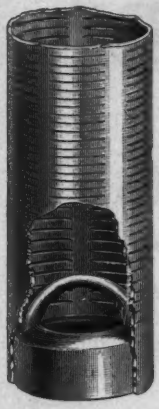

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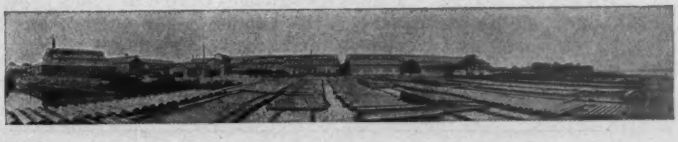

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